



315788

ANL/EES-TM-307

ANALYSIS OF INHALABLE AND FINE PARTICULATE
DATA AND EVALUATION OF THEIR
PREDICTION MODELS

RETURN TO REFERENCE FILE
TECHNICAL PUBLICATIONS
DEPARTMENT

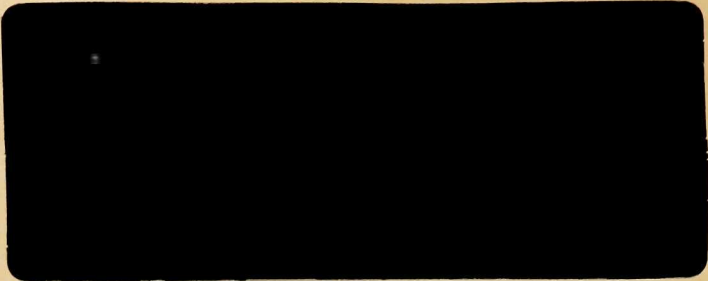


ARGONNE NATIONAL LABORATORY
Energy and Environmental Systems Division

Operated by

THE UNIVERSITY OF CHICAGO for U. S. DEPARTMENT OF ENERGY

under Contract W-31-109-Eng-38



Argonne National Laboratory, with facilities in the states of Illinois and Idaho, is owned by the United States government, and operated by The University of Chicago under the provisions of a contract with the Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This informal report presents preliminary results of ongoing work or work that is more limited in scope and depth than that described in formal reports issued by the Energy and Environmental Systems Division.

Printed in the United States of America. Available from National Technical Information Service,
U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

ANL/EES-TM-307

ANALYSIS OF INHALABLE AND FINE PARTICULATE
DATA AND EVALUATION OF THEIR
PREDICTION MODELS

by

K.C. Chun and D.J. Fingleton

Energy and Environmental Systems Division
Integrated Assessments and Policy Evaluation Group

March 1984

work sponsored by

U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Policy, Safety, and Environment
Office of Environmental Analysis

CONTENTS

| | |
|--------------------------------------------------------------------------------------------------------|----|
| ABSTRACT | 1 |
| 1 INTRODUCTION | 1 |
| 2 DATA ACQUISITION, SCREENING, AND PROCESSING | 5 |
| 3 GEOGRAPHICAL AND SEASONAL VARIABILITY OF TSP, IP15, PM10, AND FP CONCENTRATIONS | 8 |
| 3.1 Geographical Distribution | 8 |
| 3.2 Seasonal Variability | 8 |
| 4 MODELS FOR PREDICTING IP15, PM10, AND FP CONCENTRATIONS FROM TSP CONCENTRATIONS | 12 |
| 4.1 Statistical Significance of Data Stratification | 12 |
| 4.2 Predictive Ability of Average Ratio Models Obtained by Data Stratification | 18 |
| 5 POTENTIAL EFFECTS OF POSSIBLE NEW SIZE-SPECIFIC PARTICULATE NAAQS ON NONATTAINMENT PROBLEMS | 32 |
| 5.1 Assessment Based on IPM Monitoring Network Data | 32 |
| 5.2 Assessment Based on 1982 U.S. Ambient Data | 33 |
| 6 SUMMARY AND CONCLUSIONS | 37 |
| REFERENCES | 40 |
| APPENDIX: Particulate Air Quality Data | 41 |

TABLES

| | |
|-----------------------------------------------------------------------------------------------------------------------|----|
| 4.1 Statistical Significance of Variations in Particulate Ratios, Stratified by Federal Region | 16 |
| 4.2 Statistical Significance of Variations in Particulate Ratios, Stratified by Season | 16 |
| 4.3 Statistical Significance of Variations in Particulate Ratios, Stratified by Monitoring Station Site Type | 17 |
| 4.4 Statistical Significance of Variations in Particulate Ratios, Stratified by TSP Levels | 17 |
| 4.5 Statistical Significance of Variations in Particulate Ratios, Stratified by Monitoring Station Location | 18 |

TABLES (Cont'd)

| | | |
|------|----------------------------------------------------------------------------------------------------------------------------------------|----|
| 4.6 | Evaluation of the IP15/TSP Average Ratio Model for Data Sets Stratified by Region and Season | 23 |
| 4.7 | Evaluation of the PM10/TSP Average Ratio Model for Data Sets Stratified by Region and Season | 25 |
| 4.8 | Evaluation of the FP/TSP Average Ratio Model for Data Sets Stratified by Region and Season | 27 |
| 4.9 | Accuracy of Various IP15/TSP Average Ratios in Predicting IP15 Concentrations | 29 |
| 4.10 | Accuracy of Various PM10/TSP Average Ratios in Predicting PM10 Concentrations | 30 |
| 4.11 | Accuracy of Various FP/TSP Average Ratios in Predicting FP Concentrations | 31 |
| 5.1 | Actual and Potential Number of Nonattainment Counties with Respect to Current and Proposed Annual Average NAAQS for Particulates | 34 |
| 5.2 | Actual and Potential Number of Nonattainment Counties with Respect to Current and Proposed Maximum 24-hr NAAQS for Particulates | 35 |
| A.1 | IPM Monitoring Stations Meeting the Seasonal Data Requirements for 1980-1981 | 43 |
| A.2 | Concentrations of TSP in Counties Violating NAAQS for TSP in 1982 and the Estimated PM10 Concentrations in Those Counties | 47 |

FIGURES

| | | |
|-----|---------------------------------------------------------------------------------------------------------|----|
| 1.1 | Stations in the IPM Monitoring Network as of February 1982 | 3 |
| 2.1 | Monthly Average Particulate Ratios Based on IPM Monitoring Network Data, 1979-1981 | 6 |
| 3.1 | Regional Variations in Annual Average TSP, IP15, PM10, and FP Concentrations | 9 |
| 3.2 | Regional Variations in Seasonal Arithmetic Average Concentrations of FP and Coarse Mode Particles | 10 |
| 3.3 | Regional Variations in Seasonal Arithmetic Average Concentrations of FP, IP15, and TSP | 11 |
| 4.1 | Seasonal and Regional Variations in the Average IP15/TSP Ratio | 13 |
| 4.2 | Seasonal and Regional Variations in the Average PM10/TSP Ratio | 14 |

FIGURES (Cont'd)

| | | |
|-----|--------------------------------------------------------------------|----|
| 4.3 | Seasonal and Regional Variations in the Average FP/TSP Ratio | 15 |
| 4.4 | Regional Variations in Seasonal Average IP15/TSP Ratios | 20 |
| 4.5 | Regional Variations in Seasonal Average PM10/TSP Ratios | 21 |
| 4.6 | Regional Variations in Seasonal Average FP/TSP Ratios | 22 |

| | | |
|-----|--------------------------------|-----|
| 1 | 1. General and Background | 1 |
| 2 | 2. Regional Variation in the | 2 |
| 3 | 3. Regional Variation in the | 3 |
| 4 | 4. Regional Variation in the | 4 |
| 5 | 5. Regional Variation in the | 5 |
| 6 | 6. Regional Variation in the | 6 |
| 7 | 7. Regional Variation in the | 7 |
| 8 | 8. Regional Variation in the | 8 |
| 9 | 9. Regional Variation in the | 9 |
| 10 | 10. Regional Variation in the | 10 |
| 11 | 11. Regional Variation in the | 11 |
| 12 | 12. Regional Variation in the | 12 |
| 13 | 13. Regional Variation in the | 13 |
| 14 | 14. Regional Variation in the | 14 |
| 15 | 15. Regional Variation in the | 15 |
| 16 | 16. Regional Variation in the | 16 |
| 17 | 17. Regional Variation in the | 17 |
| 18 | 18. Regional Variation in the | 18 |
| 19 | 19. Regional Variation in the | 19 |
| 20 | 20. Regional Variation in the | 20 |
| 21 | 21. Regional Variation in the | 21 |
| 22 | 22. Regional Variation in the | 22 |
| 23 | 23. Regional Variation in the | 23 |
| 24 | 24. Regional Variation in the | 24 |
| 25 | 25. Regional Variation in the | 25 |
| 26 | 26. Regional Variation in the | 26 |
| 27 | 27. Regional Variation in the | 27 |
| 28 | 28. Regional Variation in the | 28 |
| 29 | 29. Regional Variation in the | 29 |
| 30 | 30. Regional Variation in the | 30 |
| 31 | 31. Regional Variation in the | 31 |
| 32 | 32. Regional Variation in the | 32 |
| 33 | 33. Regional Variation in the | 33 |
| 34 | 34. Regional Variation in the | 34 |
| 35 | 35. Regional Variation in the | 35 |
| 36 | 36. Regional Variation in the | 36 |
| 37 | 37. Regional Variation in the | 37 |
| 38 | 38. Regional Variation in the | 38 |
| 39 | 39. Regional Variation in the | 39 |
| 40 | 40. Regional Variation in the | 40 |
| 41 | 41. Regional Variation in the | 41 |
| 42 | 42. Regional Variation in the | 42 |
| 43 | 43. Regional Variation in the | 43 |
| 44 | 44. Regional Variation in the | 44 |
| 45 | 45. Regional Variation in the | 45 |
| 46 | 46. Regional Variation in the | 46 |
| 47 | 47. Regional Variation in the | 47 |
| 48 | 48. Regional Variation in the | 48 |
| 49 | 49. Regional Variation in the | 49 |
| 50 | 50. Regional Variation in the | 50 |
| 51 | 51. Regional Variation in the | 51 |
| 52 | 52. Regional Variation in the | 52 |
| 53 | 53. Regional Variation in the | 53 |
| 54 | 54. Regional Variation in the | 54 |
| 55 | 55. Regional Variation in the | 55 |
| 56 | 56. Regional Variation in the | 56 |
| 57 | 57. Regional Variation in the | 57 |
| 58 | 58. Regional Variation in the | 58 |
| 59 | 59. Regional Variation in the | 59 |
| 60 | 60. Regional Variation in the | 60 |
| 61 | 61. Regional Variation in the | 61 |
| 62 | 62. Regional Variation in the | 62 |
| 63 | 63. Regional Variation in the | 63 |
| 64 | 64. Regional Variation in the | 64 |
| 65 | 65. Regional Variation in the | 65 |
| 66 | 66. Regional Variation in the | 66 |
| 67 | 67. Regional Variation in the | 67 |
| 68 | 68. Regional Variation in the | 68 |
| 69 | 69. Regional Variation in the | 69 |
| 70 | 70. Regional Variation in the | 70 |
| 71 | 71. Regional Variation in the | 71 |
| 72 | 72. Regional Variation in the | 72 |
| 73 | 73. Regional Variation in the | 73 |
| 74 | 74. Regional Variation in the | 74 |
| 75 | 75. Regional Variation in the | 75 |
| 76 | 76. Regional Variation in the | 76 |
| 77 | 77. Regional Variation in the | 77 |
| 78 | 78. Regional Variation in the | 78 |
| 79 | 79. Regional Variation in the | 79 |
| 80 | 80. Regional Variation in the | 80 |
| 81 | 81. Regional Variation in the | 81 |
| 82 | 82. Regional Variation in the | 82 |
| 83 | 83. Regional Variation in the | 83 |
| 84 | 84. Regional Variation in the | 84 |
| 85 | 85. Regional Variation in the | 85 |
| 86 | 86. Regional Variation in the | 86 |
| 87 | 87. Regional Variation in the | 87 |
| 88 | 88. Regional Variation in the | 88 |
| 89 | 89. Regional Variation in the | 89 |
| 90 | 90. Regional Variation in the | 90 |
| 91 | 91. Regional Variation in the | 91 |
| 92 | 92. Regional Variation in the | 92 |
| 93 | 93. Regional Variation in the | 93 |
| 94 | 94. Regional Variation in the | 94 |
| 95 | 95. Regional Variation in the | 95 |
| 96 | 96. Regional Variation in the | 96 |
| 97 | 97. Regional Variation in the | 97 |
| 98 | 98. Regional Variation in the | 98 |
| 99 | 99. Regional Variation in the | 99 |
| 100 | 100. Regional Variation in the | 100 |

ANALYSIS OF INHALABLE AND FINE PARTICULATE DATA AND EVALUATION OF THEIR PREDICTION MODELS

by

K.C. Chun and D.J. Fingleton

ABSTRACT

In anticipation of size-specific ambient particulate air quality standards, the U.S. Environmental Protection Agency has established an inhalable particulate matter monitoring network on a limited scale. Simple arithmetic average ratio models for predicting inhalable particulate levels have been previously derived by others based on the inhalable particulate concentration data and colocated high-volume sampler data obtained from the monitoring network. In order to improve such models for predicting various size-specific particulate concentration levels from an expanded data base, this report (1) describes procedures for improved data screening and for calculation of concentrations for particles with aerodynamic diameters less than 10 μm , (2) tests whether the predictive ability of simple arithmetic average ratios can be improved by data stratification by key parameters, and (3) assesses the likelihood of nonattainment at the county level with respect to potential size-specific ambient particulate standards. Seasonal and regional characteristics of various size-specific and total suspended particulate concentration levels are also described.

1 INTRODUCTION

The current primary national ambient air quality standards (NAAQS) for particulate matter (to protect public health) are 75 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) as the annual geometric mean and 260 $\mu\text{g}/\text{m}^3$ as the maximum 24-hr concentration not to be exceeded more than once per year. The current secondary NAAQS for particulate matter (to protect public welfare) specify 150 $\mu\text{g}/\text{m}^3$ as the maximum 24-hr concentration not to be exceeded more than once per year. In addition, the secondary standard specifies a 60- $\mu\text{g}/\text{m}^3$ annual geometric mean as a guide for achieving the 24-hr standard.¹ The reference method for measuring particulate matter concentrations is by use of a high-volume sampler,² which effectively collects ambient particulate matter in the range of 25-45 micrometers (μm) in aerodynamic diameter. Particulates in this size range are referred to as total suspended particulates (TSP).

The current NAAQS for particulate matter were originally promulgated in 1971. These standards and their scientific basis (the air quality criteria) must be reviewed

periodically by the U.S. Environmental Protection Agency (EPA), according to Section 109(d) of the Clean Air Act Amendments of 1977. Such a review was completed in January 1982,³ and EPA has been considering recommendations to propose new primary ambient particulate standards in terms of thoracic particles, which are a new indicator for particulate matter less than a nominal 10 μm in diameter (PM10). The specific primary standards for PM10 being considered for recommendation have been fluctuating. The following ranges have been reported to be under consideration:³

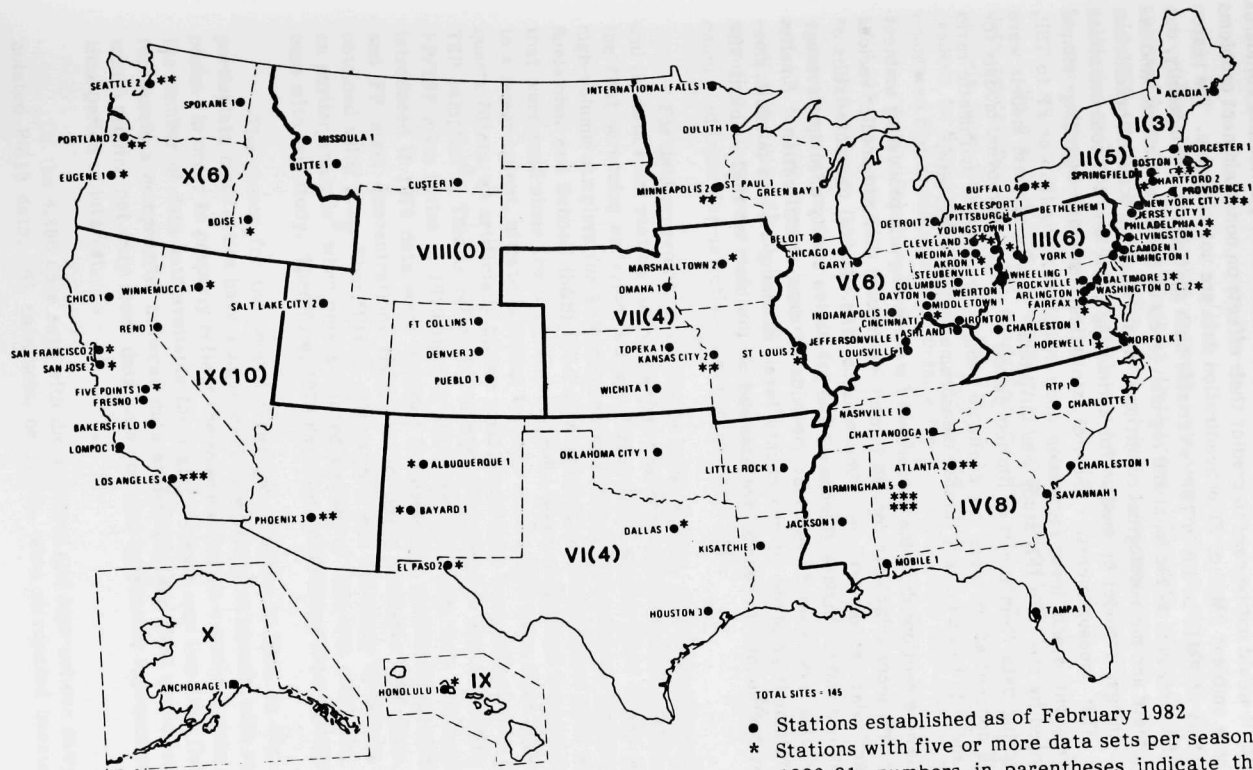
- Annual arithmetic average: 50-65 $\mu\text{g}/\text{m}^3$, and
- Maximum 24-hr concentration: 150-250 $\mu\text{g}/\text{m}^3$.

A secondary standard of 75 $\mu\text{g}/\text{m}^3$ in terms of the annual arithmetic mean TSP concentration is also under consideration for prevention of soiling and nuisance. To protect visibility, a secondary standard for fine particles (FP) less than 2.5 μm in aerodynamic diameter was also under consideration at one time. A range of 8-25 $\mu\text{g}/\text{m}^3$ of FP as a seasonal and spatial average was suggested by EPA's Clean Air Scientific Advisory Committee (CASAC) in early 1982.⁴ However, no specific FP standard is currently being discussed by EPA.

In anticipation of the possible revision of ambient standards for particulate matter to size-specific standards, EPA began in 1979 to establish an inhalable particulate matter (IPM) monitoring network. This network, consisting of about 160 sampling sites at the time of this study, is located primarily in the urban areas of selected airsheds throughout the United States (see Fig. 1.1). At each sampling site are installed a TSP high-volume sampler, a dichotomous sampler, and for comparison purposes, a high-volume sampler with a size-selective inlet. The dichotomous sampler deployed initially collected the coarse (between 2.5 μm and 15 μm in aerodynamic diameter) and fine (< 2.5 μm) particulate fractions separately. The sum of the coarse particulate (CP) and FP fractions is reported as the inhalable particulate (designated as "IP15") concentration.

The inhalable particle size cut-point of 15 μm was based on the recommendations of Miller et al.,⁵ who stated that "15 μm would be a reasonable particle cut-point to include in the design of a sampler which would differentiate particles deposited in the upper vs. lower respiratory tract." However, in 1981 the International Standards Organization recommended reducing the cut-point diameter to 10 μm based on a different interpretation of data for particulate deposition in the respiratory tract.⁶ The CASAC accepted this proposal and recommended that sampling strategies for the IPM monitoring network be revised from 15 μm to 10 μm as soon as the hardware became available. The conversions were initiated in early 1982 on a limited scale. For this study, therefore, which analyzed the IPM monitoring network data for 1980 and 1981, routinely measured PM10 data were not available.

Compared with the number of operating IPM monitoring sites, a large number of locations are being monitored for TSP (over 3600 sites in 1982).⁷ This suggests that the health and other effects of particulate matter are of concern (or at least the particulate concentrations themselves are of interest, e.g., as remote background levels), and that TSP is being monitored simply because the current ambient standards are defined in



TOTAL SITES - 145

- Stations established as of February 1982
- * Stations with five or more data sets per season, 1980-81; numbers in parentheses indicate the number of such stations in each federal region

FIGURE 1.1 Stations in the IPM Monitoring Network as of February 1982

terms of TSP. If new, size-specific (PM₁₀ and possibly FP) ambient particulate standards are promulgated, it would not be easy to predict their effects on nonattainment problems in locations where ambient PM₁₀ or FP concentration data are not available. The reason is that the fraction of PM₁₀ or FP in TSP is variable both spatially and temporally, due to a number of factors, such as the local and regional levels of human activities, land use patterns, and climate and meteorological conditions. What is needed for such predictions is, among other things, a model or models for estimating PM₁₀ and FP concentrations from available TSP measurements. Several statistical models, including simple arithmetic average ratios and linear regression slope models relating IP₁₅ or FP to TSP, had been developed by the time this study was initiated.⁸ However, these models were based on monitoring data from a rather limited period of time. Moreover, models for predicting PM₁₀ concentrations were not available except for a simple arithmetic ratio between PM₁₀ and IP₁₅ based on very limited measurements at a single site.⁹

The following sections describe procedures for screening and processing ambient inhalable particulate monitoring data for use in deriving models that can predict various size-specific particulate concentrations. The seasonal and regional characteristics of these and of TSP concentrations are described. The predictive ability of simple average ratio models is also evaluated for various methods of data stratification. Finally, potential nonattainment problems at the county level, assuming various possible size-specific ambient particulate standards, are assessed on the basis of 1982 ambient TSP data.

2 DATA ACQUISITION, SCREENING, AND PROCESSING

The IPM monitoring network data available at the time of this study were obtained from the EPA National Air Data Branch. The data, which cover the period from mid-1979 to the end of 1981, were already processed by EPA according to various validation procedures, and those data not meeting certain empirical criteria were flagged for more-extensive validation.

Several data processing and screening procedures were adopted in this study. For data processing, the PM10 concentration level was computed by assuming that the particle mass in a given ambient particulate sample is log-normally distributed with respect to particle diameter.¹⁰ This means that, for every set of dichotomous and colocated high-volume sampler data, a PM10 concentration level can be estimated if the FP mass is less than the IP15 mass and if the latter, in turn, is less than the TSP mass. Of 5,067 data sets with dichotomous and high-volume sampler data for the period from mid-1979 through 1981, 4,806 data sets (94.8% of the total) representing 80 IPM monitoring stations were usable for estimating PM10 data. Also, ratios of IP15, PM10, and FP to TSP were computed for use in developing potential statistical models for predicting IP15, PM10, and FP levels. Data from high-volume samplers with size-selective inlets were not considered in this analysis because PM10 data cannot be calculated from size-selective inlet and TSP data sets.

For data screening, two criteria were applied. Eliminated were (1) data for 1979 and (2) data from stations with less than five data sets from each season. The reason for the first screening criterion is that, during 1979, quartz fiber filters were used in the high-volume samplers for TSP monitoring at the IPM monitoring stations, instead of the Schleicher and Schnell (S&S) HV-1 EPA grade glass fiber filters with an organic binder that were used since the beginning of 1980. Since an artifact formation of sulfate and, to a lesser extent, nitrate is known to occur on the S&S glass fiber filters but not on the quartz filters, an artificially higher mass would have been collected by the 1980 to 1981 TSP samples.⁸ This is reflected in higher values for the IP15/TSP, PM10/TSP, and FP/TSP mass ratios in 1979 than in 1980 and 1981 (Fig. 2.1). Thus, an error would be introduced if 1979 data were included in developing models for predicting IP15, PM10, and FP mass concentrations from the routinely available TSP data, which are also obtained using glass fiber filters. Although it was necessary to include the 1979 data in an earlier analysis⁸ when only a limited amount of data was available, that was not the case with this study. Therefore, 1979 data were eliminated from further consideration.

The reason for the second screening criterion is that, as Fig. 2.1 shows, these particulate mass ratios have a significant dependency on season, with summer and winter peaks. In order to properly reflect the seasonal factor, a station's data were discarded if the number of data sets available for a given season was less than five. This minimum represents a compromise between data availability and good statistical practice, which would require not only more data sets but also reasonable representation of the entire time period of interest.

Of the 4,806 data sets with dichotomous and high-volume sampler data and calculated PM10 data, 561 data sets, or 11.7%, were eliminated because they contained

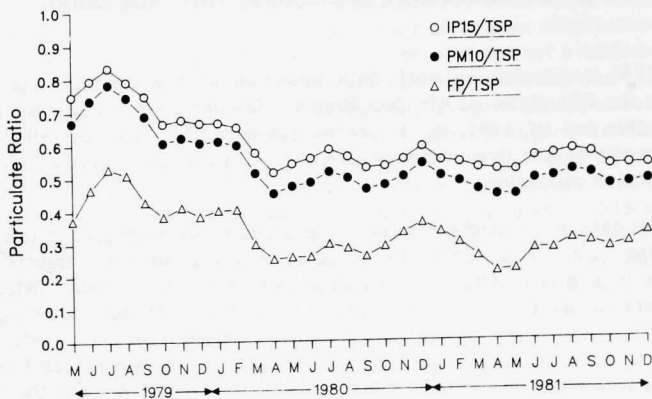


FIGURE 2.1 Monthly Average Particulate Ratios Based on IPM Monitoring Network Data, 1979-1981

1979 data. An additional 1,167 data sets, or 27.5% of the remaining sets, were eliminated for not meeting the seasonal requirement. Thus, the final number of data sets used for the analysis was 3,078, representing 52 monitoring stations located in 9 federal regions. The average number of data sets was about 15 per season per site, or 60 per site. Most of the data sets (2,705, or 89% of the total) were from 45 urban and suburban sites (88% of the total number of sites); the remaining data sets (373) were from 7 rural sites. The 52 monitoring stations are listed in Table A.1, along with corresponding particulate data. The locations of these monitoring sites are shown by asterisks in Fig. 1.1.

Additional screening criteria applied by other investigators to remove some of the IPM monitoring data flagged by EPA⁸ are as follows:

$$\frac{CP}{TSP - FP} < 0.3 \quad (1)$$

and

$$\frac{TSP - IP15}{TSP} < -0.15. \quad (2)$$

The first inequality states that CP (particulates within the 2.5-15 μm range) must equal at least 30% of the material greater than 2.5 μm for the data set to be accepted. The 30% value is presumably arbitrary and was chosen because the IPM data suggested that it was a natural dividing point for the limited data available to those investigators. Not only did the 1980-1981 IPM monitoring data not show any natural dividing point at the 30% value, but this criterion would have eliminated over 30% of the raw data sets for that period. In comparison, one of the conditions required for calculation of PM10 in this study, i.e., $CP/(TSP - FP) > 0$, removed less than 1% of the raw data sets for the 1980-1981 period. Therefore, this particular screening criterion was not adopted in this analysis.

The second inequality eliminates measurements for which the mass of IP15 exceeds that of TSP by more than 15%, as a reasonable tolerance for measurement errors. This screening criterion would have eliminated about 3% of the raw data sets for the 1980-1981 period. In comparison, an additional condition for computing PM10 in this study, i.e., $(TSP - IP15)/TSP > 0$, eliminated about 2% more. Thus, tightening up the measurement error tolerance was possible by eliminating only a small additional amount of data.

Some data sets did not meet both of the conditions required for computing PM10. Thus, the two conditions together eliminated only about 4% of the raw data instead of about 33% that would have been removed by the inequalities in Eqs. 1 and 2.

3 GEOGRAPHICAL AND SEASONAL VARIABILITY OF TSP, IP15, PM10, and FP CONCENTRATIONS

Since individual IPM monitoring stations show a wide variability in size-specific particulate concentrations, the distribution of these concentrations for 1980-1981 was examined in terms of averages for each federal region (see Fig. 1.1) and season. The numerical data providing the basis for this discussion are provided in Sec. 4 (Tables 4.6-4.8).

3.1 GEOGRAPHICAL DISTRIBUTION

The regional annual arithmetic* average concentrations of TSP, IP15, PM10, and FP are plotted in Fig. 3.1, except for Region 8, which had no IPM monitoring stations meeting the seasonal data requirement. For TSP, the regional annual average concentration ranges from 61 to 86 $\mu\text{g}/\text{m}^3$. The lowest average concentrations are found in Regions 1 and 10 (61 and 66 $\mu\text{g}/\text{m}^3$, respectively), while the highest occur in Regions 4, 6, and 7 (84, 85, and 86 $\mu\text{g}/\text{m}^3$, respectively). The pattern is somewhat similar for both IP15 and PM10. The lowest regional annual average concentrations also occur in Regions 1 and 10 (32 and 33 $\mu\text{g}/\text{m}^3$, respectively, for IP15 and 29 $\mu\text{g}/\text{m}^3$ in both regions for PM10). The highest annual average concentrations are in Regions 4 and 7 (47 $\mu\text{g}/\text{m}^3$ in both regions for IP15 and 42 and 41 $\mu\text{g}/\text{m}^3$, respectively, for PM10).

The regional pattern of annual average FP concentrations is somewhat different from that for the other particulates, which include coarser particles. Regions in the eastern United States in general show substantially higher FP concentrations than the rest of the country. The highest levels are found in Regions 2, 3, and 5 (25 $\mu\text{g}/\text{m}^3$) and the lowest in Region 6 (15 $\mu\text{g}/\text{m}^3$), followed by Regions 10, 9, and 1 (16, 17, and 18 $\mu\text{g}/\text{m}^3$, respectively).

3.2 SEASONAL VARIABILITY

In general, atmospheric aerosol mass shows a bimodal distribution with two distinct size modes: fine (<2.5 μm in aerodynamic diameter) and coarse (>2.5 μm).[†]

*The average concentrations in the current NAAQS for TSP are defined as the geometric average. However, average concentrations for PM10 are expected to be defined in terms of arithmetic average in the forthcoming NAAQS for particulate matter. Since the models relating PM10 and TSP are derived in terms of arithmetic averages, particulate concentrations are also described here in terms of arithmetic average. Unless otherwise noted, the term *average* hereafter means *arithmetic average* in this report.

[†]Coarse mode particle levels are calculated as TSP minus FP. This should not be confused with CP (coarse particulates between 2.5 and 15 μm in diameter), levels of which are calculated as IP15 minus FP. The definitions of fine mode particles and FP are identical.

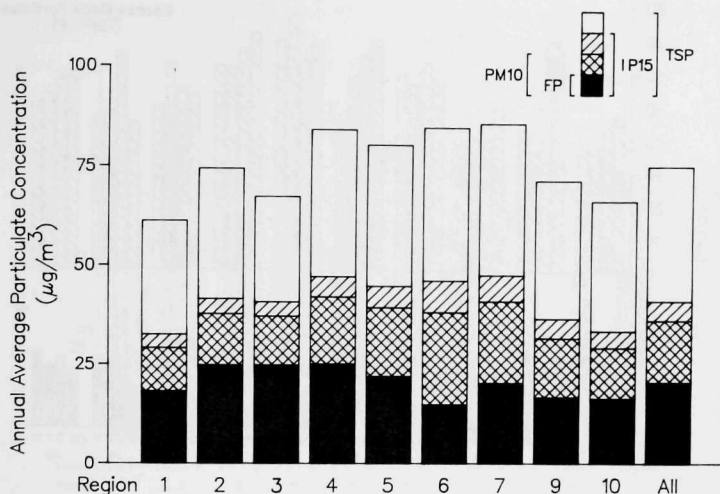


FIGURE 3.1 Regional Variations in Annual Average TSP, IP15, and PM10, and FP Concentrations (Region 8 is excluded because of insufficient seasonal data)

Although substantial overlap can exist, these modes tend to have more or less distinct origins, elemental distributions, residence times, and removal processes. Fine mode particles originate in the nuclei mode by condensation of materials produced during combustion or atmospheric transformation. Due to long residence times and atmospheric formation, FP levels can build up far from source regions over large geographical areas. Coarse mode particles are largely derived from mechanical processes such as grinding or wind erosion. Because they settle out more rapidly, elevated levels of coarse mode particles usually occur near strong emission sources.³

Since the activity levels of the processes that generate FP and coarse mode particles are strongly dependent on season, the seasonal averages of the regional concentrations of these particles are shown in Fig. 3.2. Nationwide, coarse mode particle concentrations are lowest in winter but highest during spring and summer, when human activities that disturb the earth's surface, such as agriculture, are at their peak. Regionally, spring peaks are exhibited in the East (Regions 1, 2, and 3) and middle part of the country (Regions 5 and 7). Primary or secondary peaks are prevalent in summer for Regions 2, 3, 4, 5, 7, and 10. Fall and winter seasons show relatively low coarse mode particle concentrations except in Regions 6 and 9.

In contrast, FP concentrations are highest on a nationwide basis during winter, coinciding with the highest level of fuel combustion for space heating. The next highest FP concentration levels occur in summer, when the atmospheric transformation of gaseous pollutants to FP is at its peak level. The lowest average FP concentrations are

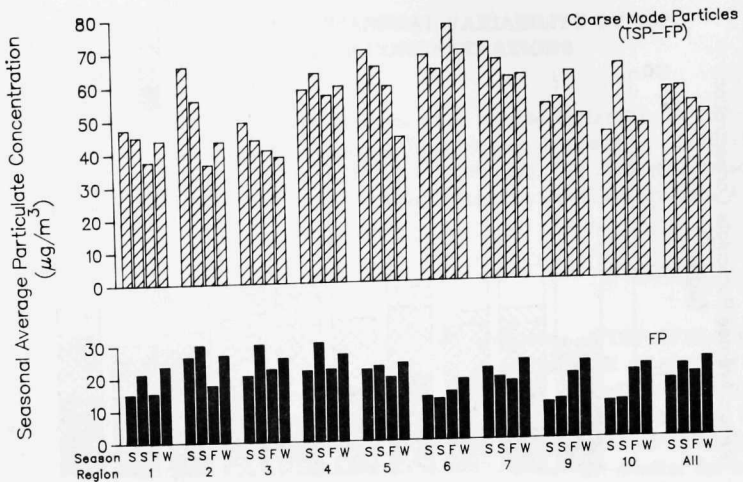


FIGURE 3.2 Regional Variations in Seasonal Arithmetic Average Concentrations of FP and Coarse Mode Particles (Region 8 is excluded because of insufficient seasonal data)

in spring. Regionally, FP concentrations are highest during summer in the East (Regions 2, 3, and 4). However, primary winter peaks exist throughout the nation, except for the three eastern regions where the winter peaks are lower than the summer peaks (although higher than the winter peaks of many other regions).

Seasonal concentration patterns of TSP are determined by those of coarse mode particles and FP, while seasonal concentration patterns of IP15 and PM10 are determined by those of CP and FP. Figure 3.3 shows the regional seasonal averages of TSP, IP15, and FP concentrations (PM10 concentrations are not shown because they follow the pattern of IP15 levels without significant deviation). Because the coarse mode particle mass contribution to TSP is on the average about 2.7 times that of the FP mass (the range is 1.5 to 5.5 times the FP contribution), the seasonal pattern of regional average TSP concentrations is largely determined by that of coarse mode particles.

In comparison, the FP mass contribution is much more important to IP15 (and PM10) concentration levels than it is to TSP concentration levels. The average FP contribution to IP15 levels is 52% (the regional seasonal range is 33% to 65%). High FP concentrations in summer and winter over the eastern United States are primarily responsible for the seasonal IP15 peaks in those regions. For the rest of the country, the CP mass contribution to IP15 is greater than that of FP for most seasons. However, because the seasonal variability of FP levels is more pronounced than that of the CP contribution to IP15, seasonal IP15 concentration levels are still largely determined by FP concentrations.

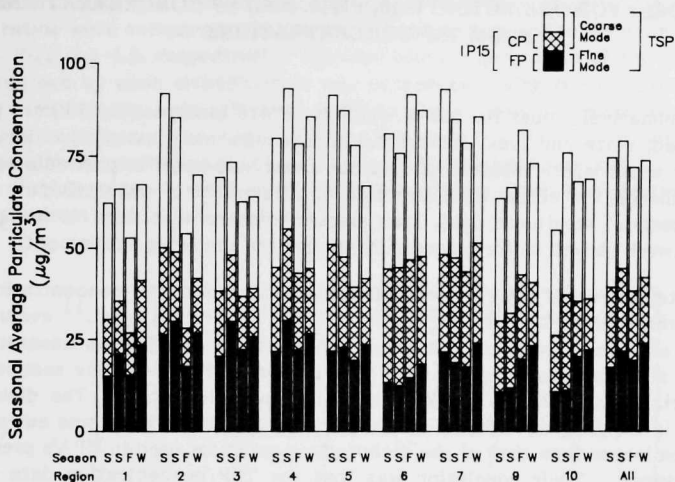


FIGURE 3.3 Regional Variations in Seasonal Arithmetic Average Concentrations of FP, IP15, and TSP (Region 8 is excluded because of insufficient seasonal data)

4 MODELS FOR PREDICTING IP15, PM10, AND FP CONCENTRATIONS FROM TSP CONCENTRATIONS

Once numerical values for the NAAQS for PM10 (and possibly FP) are proposed and promulgated, state and local environmental agencies must assess the likelihood of attainment for areas where monitoring data for these size-specific particulates are not available. Although the actual determination of attainment or nonattainment must be made on the basis of monitored data, such assessments are necessary for designing the monitoring network as well as for planning strategies for achieving attainment.

Receptor-oriented models for estimating IP15 from TSP concentrations have been derived and evaluated by a few investigators.^{8,11} Trijonis et al.¹¹ evaluated the average ratio and linear regression models that relate IP and TSP concentration data obtained from simultaneous sampling with dichotomous and high-volume samplers in St. Louis, Missouri, during EPA's 1976 Regional Air Monitoring Study. The dichotomous samplers used in the program were of an early make,¹² and the upper size cut-point was estimated to be larger than that of the dichotomous samplers used in EPA's present IPM monitoring network. Their conclusion was that the TSP concentration data obtained using high-volume samplers were poor predictors of IP15 concentrations on a daily basis. These investigators also stratified their data with respect to position, time, and meteorology, and found that estimates of the average ratio of IP15 to TSP were not substantially refined by the stratification.

Watson et al.⁸ also evaluated average slope (ratio) and linear regression relationships in the concentration data for IP15 and TSP, and for FP and TSP. These relationships were derived from the rather limited data available from the IPM monitoring network at the time of their analysis. They concluded that both types of relationships are reasonable models for estimating IP15 from TSP data, but not for estimating FP. Although the authors showed that the accuracy of the two models was not significantly different, they stated a preference for the simpler average ratio model. They also concluded that the annual average IP15/TSP ratio was a reasonable predictor for individual high 24-hr IP15 concentrations as well, but that stratification by neither TSP concentration range nor site type (e.g., urban residential) improved the predictive ability of average ratio models.

Part of this study was aimed at determining whether data stratification could improve the predictive ability of average ratio models. The models examined were derived from an expanded data base (covering 1980-81) screened using the improved criteria discussed in Sec. 2. The findings are discussed below.

4.1 STATISTICAL SIGNIFICANCE OF DATA STRATIFICATION

Average ratio models for predicting IP15, PM10, and FP concentrations from TSP data were calculated for each group of particulate data sets, stratified by federal region, season, monitoring site type and location (e.g., urban vs rural), and TSP concentration range. (These parameters do not constitute an exhaustive list of those that may cause significant variations in the particulate ratios. However, other parameters were not

examined in this study.) The seasonal and regional averages of IP15/TSP, PM10/TSP, and FP/TSP ratios were compared with the corresponding nationwide annual averages and are shown in Figs. 4.1-4.3, respectively. The statistical significance of the variations in the ratios obtained by each stratification was determined using the Duncan multiple-range test.¹³ Although the application of multiple-range tests is limited to pairwise mean differences in balanced one-way classification, their use in applications to unbalanced design (as with the stratified data sets in this study) has been suggested.¹⁴ The results of the test (which suggest statistically different groups of average ratios by different letters) are presented in Tables 4.1-4.5.

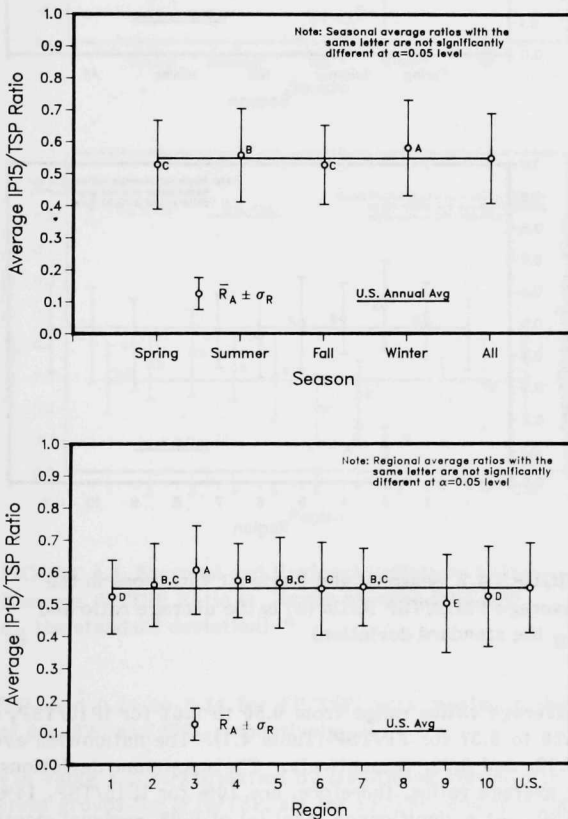


FIGURE 4.1 Seasonal and Regional Variations in the Average IP15/TSP Ratio (\bar{R}_A is the average ratio and σ_R the standard deviation)

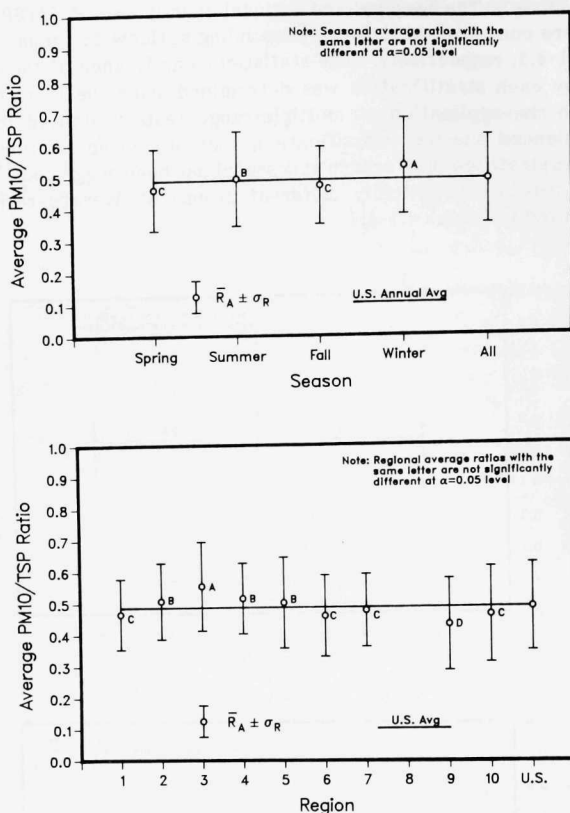


FIGURE 4.2 Seasonal and Regional Variations in the Average PM10/TSP Ratio (\bar{R}_A is the average ratio and σ_R the standard deviation)

Regional average ratios range from 0.50 to 0.61 for IP15/TSP, 0.43 to 0.55 for PM10/TSP, and 0.20 to 0.37 for FP/TSP (Table 4.1). The nationwide averages for these ratios are 0.55, 0.49, and 0.28, respectively. The maximum deviations of the regional from the national average ratios, therefore, are 10% for IP15/TSP, 14% for PM10/TSP, and 32% for FP/TSP. At a significance level (α) of 0.05, regional stratification yielded five statistically different groups of ratios for IP15/TSP ratios, four for PM10/TSP, and seven for FP/TSP.

With respect to seasonal stratification, there are three statistically different groups of particulate ratios, with the winter high and the spring low, for all three particulate ratios (Table 4.2). These ratios range from 0.53 to 0.58 for IP15/TSP, 0.46 to

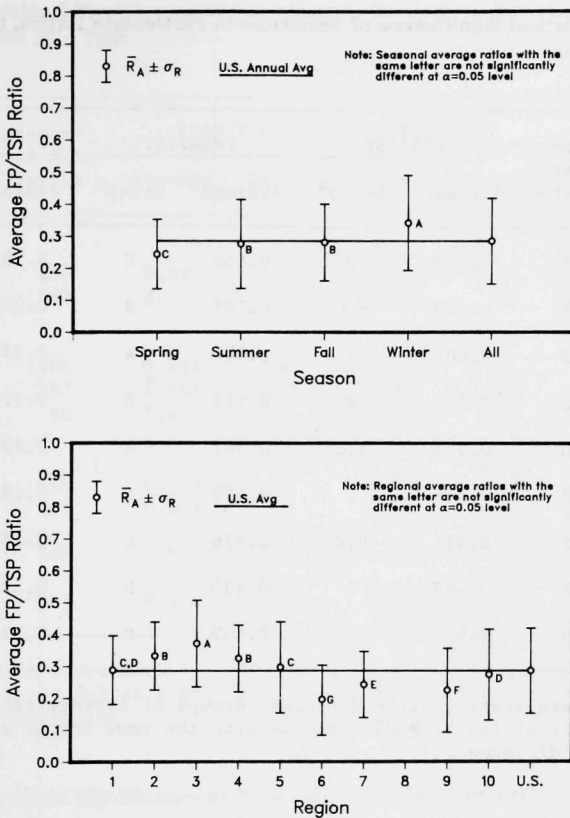


FIGURE 4.3 Seasonal and Regional Variations in the Average FP/TSP Ratio (\bar{R}_A is the average ratio and σ_R the standard deviation)

0.53 for PM10/TSP, and 0.24 to 0.34 for FP/TSP, with maximum deviations from the annual averages of 6%, 8%, and 20%, respectively.

As shown in Table 4.3, stratification by monitoring station site type yields three statistically different groups for IP15/TSP, six for FP/TSP, and four for PM10/TSP. The ratios range from 0.48 to 0.58 for IP15/TSP, 0.40 to 0.53 for PM10/TSP, and 0.13 to 0.34 for FP/TSP, with maximum deviations from the averages for all site types of 13%, 18%, and 54%, respectively. In general, the IP15/TSP and PM10/TSP ratios are higher in residential than in industrial and commercial areas, and the FP/TSP ratios are higher in urban than in rural areas.

TABLE 4.1 Statistical Significance of Variations in Particulate Ratios, Stratified by Federal Region

| Federal Region | Number of Data Points | IP15/TSP | | PM10/TSP | | FP/TSP | |
|----------------|-----------------------|----------|--------------------|----------|--------------------|---------|--------------------|
| | | Average | Group ^a | Average | Group ^a | Average | Group ^a |
| I | 227 | 0.522 | D | 0.466 | C | 0.288 | C,D |
| II | 277 | 0.559 | B,C | 0.507 | B | 0.332 | B |
| III | 383 | 0.605 | A | 0.554 | A | 0.370 | A |
| IV | 482 | 0.571 | B | 0.515 | B | 0.324 | B |
| V | 330 | 0.565 | B,C | 0.501 | B | 0.296 | C |
| VI | 237 | 0.546 | C | 0.459 | C | 0.195 | G |
| VII | 245 | 0.551 | B,C | 0.476 | C | 0.242 | E |
| IX | 548 | 0.499 | E | 0.431 | D | 0.224 | F |
| X | 349 | 0.521 | D | 0.462 | C | 0.273 | D |

^aLetters indicate statistically different groups of average ratios at a significance level (α) of 0.05. Ratios with the same letter are not statistically different.

TABLE 4.2 Statistical Significance of Variations in Particulate Ratios, Stratified by Season

| Season | Number of Data Points | IP15/TSP | | PM10/TSP | | FP/TSP | |
|--------|-----------------------|----------|--------------------|----------|--------------------|---------|--------------------|
| | | Average | Group ^a | Average | Group ^a | Average | Group ^a |
| Winter | 739 | 0.581 | A | 0.527 | A | 0.342 | A |
| Summer | 734 | 0.558 | B | 0.491 | B | 0.276 | B |
| Fall | 827 | 0.528 | C | 0.469 | C | 0.281 | B |
| Spring | 778 | 0.528 | C | 0.459 | C | 0.244 | C |

^aLetters indicate statistically different groups of average ratios at a significance level (α) of 0.05. Ratios with the same letter are not statistically different.

TABLE 4.3 Statistical Significance of Variations in Particulate Ratios, Stratified by Monitoring Station Site Type

| Land Use, Location | Number of Data Points | IP15/TSP | | PM10/TSP | | FP/TSP | |
|-----------------------|-----------------------------|----------|--------------------|----------|--------------------|---------|--------------------|
| | | Average | Group ^a | Average | Group ^a | Average | Group ^a |
| Industrial | | | | | | | |
| Urban | 489 | 0.557 | A | 0.497 | B | 0.297 | B,C |
| Suburban | 197 | 0.475 | C | 0.414 | D | 0.232 | E |
| Commercial | | | | | | | |
| Urban | 1105 | 0.533 | B | 0.470 | C | 0.271 | D |
| Suburban | 147 | 0.547 | A,B | 0.484 | B,C | 0.282 | C,D |
| Rural | 80 | 0.495 | C | 0.397 | D | 0.130 | F |
| Residential | | | | | | | |
| Urban | 95 | 0.579 | A | 0.504 | A,B | 0.254 | D,E |
| Suburban | 672 | 0.579 | A | 0.526 | A | 0.343 | A |
| Agricultural | 180 | 0.577 | A | 0.500 | B | 0.247 | E |
| Other | 113 | 0.562 | A | 0.523 | A,B | 0.315 | B |

^aLetters indicate statistically different groups of average ratios at a significance level (α) of 0.05. Ratios with the same letter are not statistically different.

TABLE 4.4 Statistical Significance of Variations in Particulate Ratios, Stratified by TSP Levels

| Annual Average TSP Level ($\mu\text{g}/\text{m}^3$) | Number of Data Points | IP15/TSP | | PM10/TSP | | FP/TSP | |
|----------------------------------------------------------------|-----------------------------|----------|--------------------|----------|--------------------|---------|--------------------|
| | | Average | Group ^a | Average | Group ^a | Average | Group ^a |
| < 100 | 2439 | 0.550 | A | 0.490 | A | 0.294 | A |
| ≥ 100 | 639 | 0.541 | A | 0.470 | B | 0.250 | B |

^aLetters indicate statistically different groups of average ratios at a significance level (α) of 0.05. Ratios with the same letter are not statistically different.

TABLE 4.5 Statistical Significance of Variations in Particulate Ratios, Stratified by Monitoring Station Location

| Station Location | Number of Data Points | IP15/TSP | | PM10/TSP | | FP/TSP | |
|--------------------|-----------------------|----------|--------------------|----------|--------------------|---------|--------------------|
| | | Average | Group ^a | Average | Group ^a | Average | Group ^a |
| Urban and suburban | 2705 | 0.547 | A | 0.487 | A | 0.291 | A |
| Rural | 373 | 0.555 | A | 0.479 | A | 0.242 | B |

^aLetters indicate statistically different groups of average ratios at a significance level (α) of 0.05. Ratios with the same letter are not statistically different.

Stratification by annual average TSP concentration ranges divided at $100 \mu\text{g}/\text{m}^3$ gives significantly different values for FP/TSP and PM10/TSP, but not for IP15/TSP (Table 4.4). The FP/TSP ratio for all TSP concentration ranges is 0.285. For the high TSP range, it is 0.25 (2% smaller) and for the low TSP range, it is 0.29 (only 3% larger). Although the PM10/TSP ratios for the two TSP ranges are statistically different at a significance level of 0.05, they differ from the ratio for all TSP concentration ranges by less than 3%.

Stratification by land use category, i.e., rural versus urban and suburban, did not yield statistically significant differences in the IP15/TSP and PM10/TSP ratios (Table 4.5). For FP/TSP, however, the difference is statistically significant, with the urban and suburban ratios high and the rural ratios low, confirming the same pattern observed in Table 4.3. The deviation from all land use categories (0.285) is only 2% for the urban-suburban FP/TSP ratio (0.29), but 15% for the rural ratio (0.24).

4.2 PREDICTIVE ABILITY OF AVERAGE RATIO MODELS OBTAINED BY DATA STRATIFICATION

It was shown in the previous section that the geographic region (federal region), season, and monitoring site type are among the important parameters that cause statistically significant variations in the average IP15/TSP, PM10/TSP, and FP/TSP ratios. Average ratio models for estimating IP15, PM10, and FP concentrations from routinely monitored TSP data were calculated by stratifying the screened IPM monitoring network data base according to federal region and season. However, monitoring station type was excluded from further consideration because (1) certain site types were represented by only a small number of stations and (2) the regions were not equally represented by all monitoring site types, which may have resulted in a biased influence

on regional average particulate ratios by certain site types.* The predictive ability of the models that were calculated was then evaluated and compared with that of the nationwide annual average ratios, and the results are presented in this section.

A given average ratio model was determined to be a better predictor than others if it met the following criteria:

1. The standard deviation of the average ratio was significantly smaller than that associated with the other average ratios,
2. The correlation coefficient of the linear regression relationship was significantly larger, and
3. The distribution of percentage differences between predicted and measured values was shifted to lower percentage differences.

The seasonal average ratios of IP15/TSP, PM10/TSP, and FP/TSP for each region were compared with the corresponding nationwide seasonal and annual average ratios and are plotted in Figs. 4.4-4.6.

The average concentrations of IP15, PM10, and FP, their ratios to colocated TSP levels as stratified by federal region, season, and both, and the evaluation results according to the three criteria above are presented in Tables 4.6-4.8. The percentage error listed in these tables is the absolute value of the percentage difference between the measured (or calculated in the case of PM10) and predicted values. If the average ratio model derived from a stratified subset of all data shows a shift in the error distribution toward lower errors than would be the case with an average ratio model derived from the overall (or a larger) data set (including the subset), then the former would be a better predictor than the latter.

An examination of Tables 4.6-4.8 reveals that regional stratification (based on nine regions) results in:

1. Standard deviations of the average ratios that for most regions (seven for IP15/TSP, seven for PM10/TSP, and six for FP/TSP) are the same as or slightly smaller than the standard deviation of the nationwide average ratio,
2. Correlation coefficients that for more than half of the regions (six for IP15/TSP, seven for PM10/TSP, and five for FP/TSP) are the same as or slightly larger than the nationwide correlation coefficient, and

*However, an inspection of the differences and scatters among individual average particulate ratios of different monitoring site types within each region suggests that seriously biased influence by any particular site type would be unlikely.

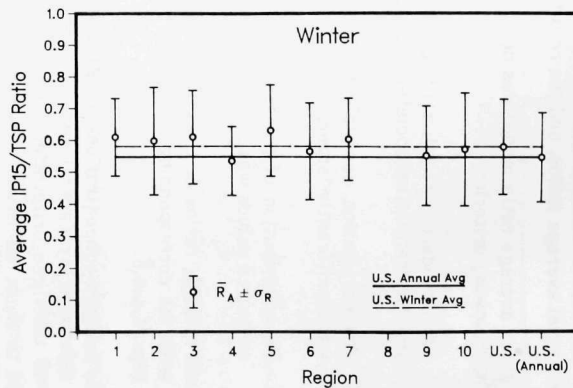
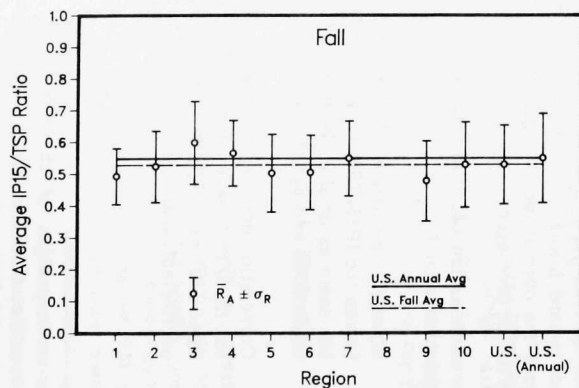
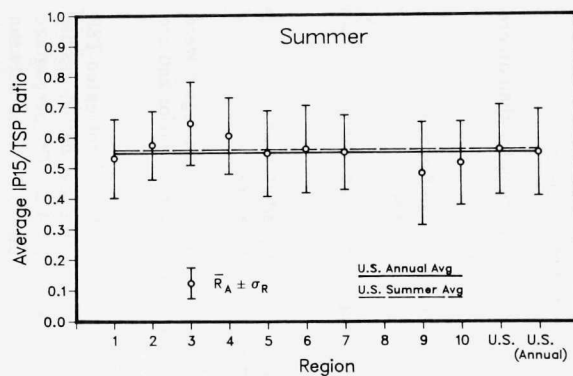
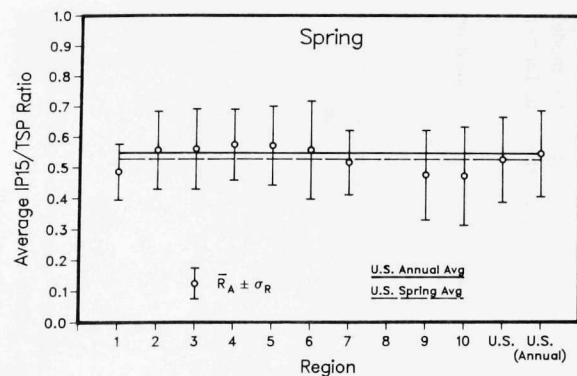


FIGURE 4.4 Regional Variations in Seasonal Average IP15/TSP Ratios (\bar{R}_A is the average ratio and σ_R the standard deviation)

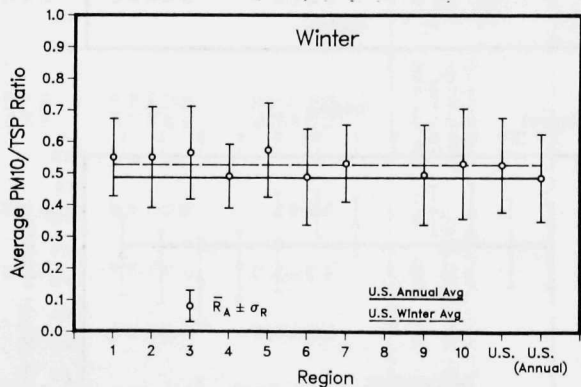
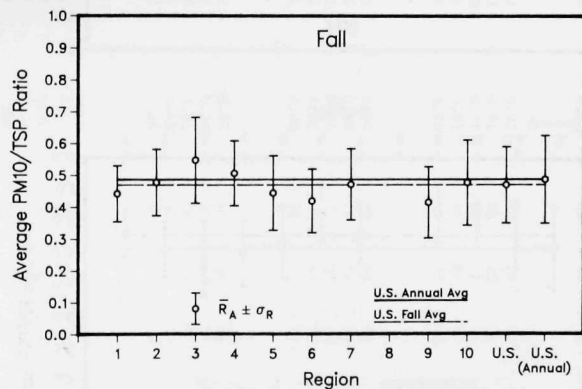
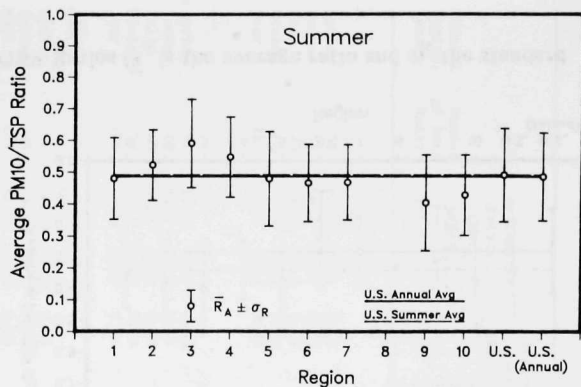
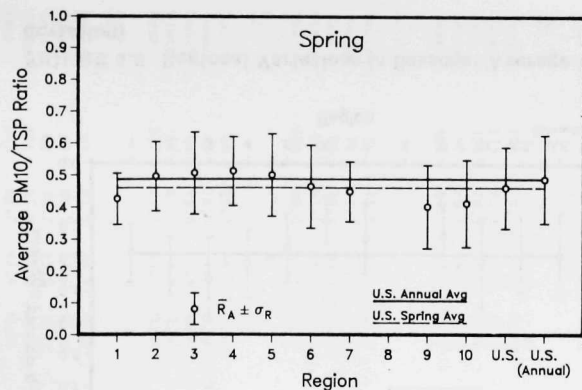


FIGURE 4.5 Regional Variations in Seasonal Average PM10/TSP Ratios (\bar{R}_A is the average ratio and σ_R the standard deviation)

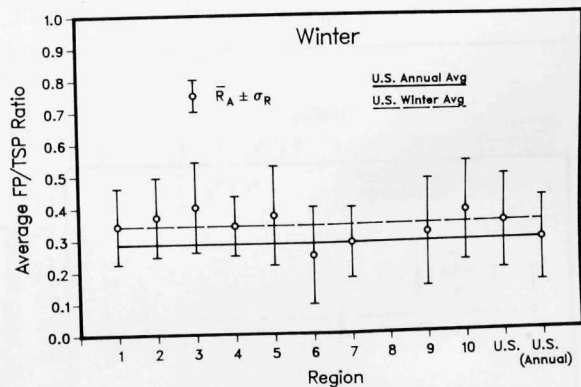
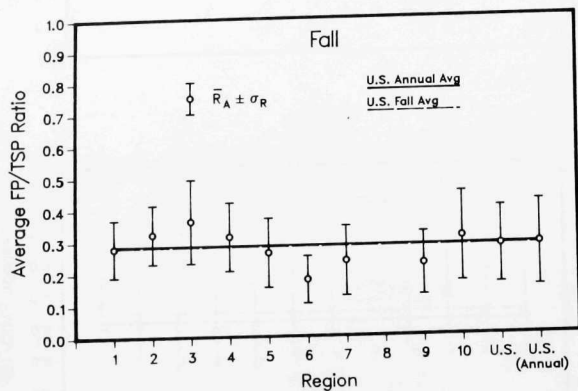
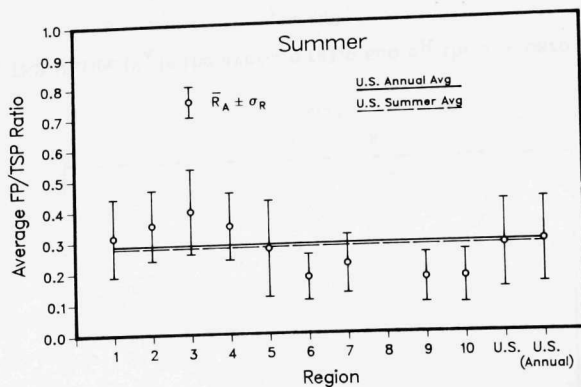
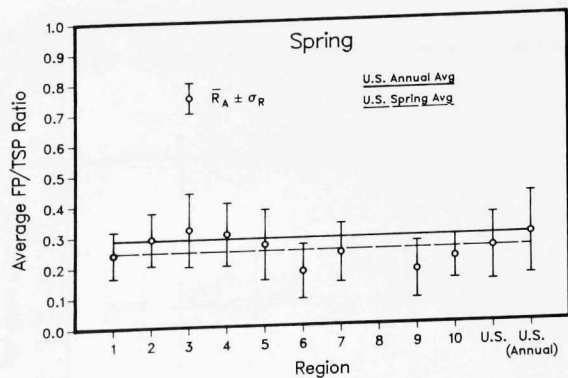


FIGURE 4.6 Regional Variations in Seasonal Average FP/TSP Ratios (\bar{R}_A is the average ratio and σ_R the standard deviation)

TABLE 4.6 Evaluation of the IP15/TSP Average Ratio Model for Data Sets Stratified by Region and Season

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc. ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average IP15/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted IP15 Values in Each Percentage Error Range | | | | |
|------------------------------|----------------------------|----------------------------------------------------------------|------|-----------------------------------------|-----------------------------------------|-------------------------------------------------------|--------------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (\bar{R}_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>I</u> | | | | | | | | | | | |
| Spring | 59 | 62.3 | 30.4 | 0.49 | 0.09 | 0.82 | 46 | 76 | 90 | 95 | 98 |
| Summer | 53 | 66.2 | 35.5 | 0.53 | 0.13 | 0.82 | 36 | 70 | 83 | 91 | 94 |
| Fall | 73 | 52.8 | 26.7 | 0.49 | 0.09 | 0.91 | 48 | 77 | 96 | 99 | 99 |
| Winter | 42 | 67.3 | 41.1 | 0.61 | 0.12 | 0.94 | 33 | 69 | 90 | 95 | 100 |
| Year | 227 | 61.1 | 32.4 | 0.52 | 0.11 | 0.89 | 41 | 70 | 87 | 92 | 96 |
| <u>II</u> | | | | | | | | | | | |
| Spring | 61 | 92.0 | 50.1 | 0.56 | 0.13 | 0.76 | 39 | 59 | 80 | 95 | 98 |
| Summer | 80 | 85.4 | 49.0 | 0.57 | 0.11 | 0.88 | 43 | 71 | 90 | 95 | 98 |
| Fall | 86 | 54.0 | 28.0 | 0.52 | 0.11 | 0.81 | 45 | 71 | 83 | 91 | 97 |
| Winter | 50 | 70.0 | 41.7 | 0.60 | 0.17 | 0.79 | 36 | 60 | 78 | 80 | 86 |
| Year | 277 | 74.3 | 41.4 | 0.56 | 0.13 | 0.85 | 39 | 65 | 82 | 92 | 96 |
| <u>III</u> | | | | | | | | | | | |
| Spring | 81 | 69.3 | 38.3 | 0.56 | 0.13 | 0.90 | 42 | 64 | 83 | 94 | 95 |
| Summer | 98 | 73.4 | 48.2 | 0.64 | 0.14 | 0.90 | 39 | 68 | 83 | 93 | 99 |
| Fall | 105 | 62.7 | 36.8 | 0.60 | 0.13 | 0.90 | 43 | 70 | 88 | 92 | 95 |
| Winter | 99 | 64.0 | 38.9 | 0.61 | 0.15 | 0.90 | 29 | 52 | 83 | 89 | 98 |
| Year | 383 | 67.2 | 40.6 | 0.61 | 0.14 | 0.89 | 35 | 64 | 84 | 91 | 96 |
| <u>IV</u> | | | | | | | | | | | |
| Spring | 134 | 79.9 | 44.7 | 0.57 | 0.12 | 0.92 | 43 | 69 | 84 | 93 | 100 |
| Summer | 125 | 93.2 | 55.3 | 0.60 | 0.13 | 0.91 | 48 | 75 | 86 | 94 | 96 |
| Fall | 125 | 78.5 | 43.2 | 0.56 | 0.10 | 0.87 | 45 | 77 | 92 | 98 | 98 |
| Winter | 98 | 85.7 | 44.4 | 0.54 | 0.11 | 0.91 | 41 | 67 | 87 | 95 | 99 |
| Year | 482 | 84.1 | 47.0 | 0.57 | 0.12 | 0.90 | 44 | 73 | 87 | 94 | 98 |
| <u>V</u> | | | | | | | | | | | |
| Spring | 76 | 91.5 | 51.1 | 0.57 | 0.13 | 0.90 | 29 | 63 | 86 | 91 | 96 |
| Summer | 76 | 87.5 | 47.7 | 0.55 | 0.14 | 0.89 | 24 | 53 | 78 | 87 | 96 |
| Fall | 85 | 78.1 | 39.3 | 0.50 | 0.12 | 0.91 | 32 | 59 | 78 | 91 | 96 |
| Winter | 93 | 67.1 | 41.7 | 0.63 | 0.14 | 0.88 | 40 | 65 | 83 | 86 | 98 |
| Year | 330 | 80.3 | 44.6 | 0.56 | 0.14 | 0.89 | 28 | 59 | 79 | 89 | 95 |
| <u>VI</u> | | | | | | | | | | | |
| Spring | 60 | 81.2 | 44.3 | 0.56 | 0.16 | 0.83 | 27 | 42 | 63 | 78 | 97 |
| Summer | 49 | 76.0 | 44.7 | 0.56 | 0.14 | 0.94 | 27 | 63 | 80 | 86 | 94 |
| Fall | 64 | 91.8 | 46.8 | 0.50 | 0.12 | 0.91 | 28 | 56 | 83 | 95 | 98 |
| Winter | 64 | 87.6 | 47.8 | 0.57 | 0.15 | 0.88 | 47 | 72 | 78 | 86 | 88 |
| Year | 237 | 84.7 | 46.0 | 0.55 | 0.14 | 0.88 | 30 | 59 | 76 | 88 | 94 |
| <u>VII</u> | | | | | | | | | | | |
| Spring | 67 | 93.2 | 48.3 | 0.52 | 0.10 | 0.88 | 42 | 66 | 87 | 94 | 100 |
| Summer | 58 | 85.2 | 47.4 | 0.55 | 0.12 | 0.86 | 38 | 69 | 83 | 91 | 97 |
| Fall | 69 | 78.7 | 43.5 | 0.55 | 0.12 | 0.91 | 38 | 70 | 84 | 94 | 97 |
| Winter | 51 | 85.8 | 51.5 | 0.60 | 0.13 | 0.77 | 29 | 69 | 86 | 92 | 96 |
| Year | 245 | 85.7 | 47.4 | 0.55 | 0.12 | 0.86 | 39 | 67 | 83 | 93 | 97 |

TABLE 4.6 (Cont'd)

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc. ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average IP15/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted IP15 Values in Each Percentage Error Range | | | | |
|------------------------------|----------------------------|----------------------------------------------------------------|------|-----------------------------------------|-----------------------------------------|-------------------------------------------------------|--------------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (\bar{R}_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>IX</u> | | | | | | | | | | | |
| Spring | 142 | 63.7 | 30.0 | 0.48 | 0.15 | 0.84 | 32 | 60 | 73 | 83 | 90 |
| Summer | 127 | 66.7 | 32.2 | 0.48 | 0.17 | 0.75 | 24 | 40 | 62 | 81 | 87 |
| Fall | 125 | 82.3 | 42.8 | 0.48 | 0.13 | 0.97 | 34 | 58 | 71 | 84 | 94 |
| Winter | 154 | 73.1 | 40.6 | 0.55 | 0.16 | 0.90 | 29 | 56 | 73 | 84 | 92 |
| Year | 548 | 71.3 | 36.4 | 0.50 | 0.15 | 0.90 | 31 | 54 | 71 | 83 | 88 |
| <u>X</u> | | | | | | | | | | | |
| Spring | 98 | 55.0 | 26.1 | 0.57 | 0.16 | 0.91 | 29 | 50 | 67 | 74 | 85 |
| Summer | 68 | 76.1 | 37.2 | 0.51 | 0.14 | 0.86 | 25 | 60 | 75 | 84 | 94 |
| Fall | 95 | 68.2 | 35.5 | 0.53 | 0.13 | 0.83 | 29 | 58 | 75 | 89 | 96 |
| Winter | 88 | 68.6 | 36.1 | 0.57 | 0.18 | 0.77 | 26 | 44 | 72 | 80 | 88 |
| Year | 349 | 66.1 | 33.3 | 0.52 | 0.16 | 0.83 | 26 | 54 | 72 | 82 | 89 |
| <u>Nation</u> | | | | | | | | | | | |
| Spring | 778 | 74.7 | 39.3 | 0.53 | 0.14 | 0.89 | 34 | 61 | 77 | 87 | 92 |
| Summer | 734 | 79.2 | 44.5 | 0.56 | 0.15 | 0.86 | 32 | 61 | 78 | 87 | 93 |
| Fall | 827 | 72.1 | 38.3 | 0.53 | 0.12 | 0.91 | 37 | 64 | 82 | 92 | 96 |
| Winter | 739 | 73.9 | 41.9 | 0.58 | 0.15 | 0.86 | 33 | 79 | 87 | 93 | 97 |
| Year | 3,078 | 74.9 | 40.9 | 0.55 | 0.14 | 0.88 | 33 | 61 | 78 | 88 | 93 |

3. More predicted values falling within lower percentage error ranges for most regions. For example, the percentage of predicted values with a percentage error of $\leq 30\%$ is higher based on regional average ratios than on the national average ratio in the case of six regions for IP15, six for PM10, and five for FP.

Most of the improvements in predictive ability resulting from regional data stratification are observed in the eastern United States. Improvements there are particularly notable in the correlation coefficient between FP and TSP, with increases of 19-25% in Regions 1, 2, and 3 (from 0.63 to up to 0.79). Most cases of deterioration in these statistics occur in the West Coast regions (Regions 9 and 10).

The effects of seasonal stratification for individual regions or the entire United States is not apparent in Tables 4.6-4.8, because only a few instances show a clear-cut improvement in these criteria for all four seasons. To more easily evaluate the effects of data stratification by region and season, the numbers of predicted values (obtained using regional seasonal ratios) within given levels of relative error were summed for all four seasons. This was done for each region as well as for all regions combined. Tables 4.9-4.11 compare these total numbers, expressed as cumulative percentages, with the cumulative percentages obtained by using the U.S. and regional annual average ratios, within given percentage error levels, for IP15/TSP, PM10/TSP, and FP/TSP. The

TABLE 4.7 Evaluation of the PM₁₀/TSP Average Ratio Model for Data Sets Stratified by Region and Season

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc. ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average PM10/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted PM10 Values in Each Percentage Error Range | | | | |
|------------------------------|----------------------------|----------------------------------------------------------------|------|-----------------------------------------|-----------------------------------------|-------------------------------------------------------|--------------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (\bar{R}_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>I</u> | | | | | | | | | | | |
| Spring | 59 | 62.3 | 26.6 | 0.43 | 0.08 | 0.83 | 37 | 76 | 92 | 93 | 98 |
| Summer | 53 | 66.2 | 32.1 | 0.48 | 0.13 | 0.80 | 40 | 62 | 79 | 91 | 94 |
| Fall | 73 | 52.8 | 24.0 | 0.44 | 0.09 | 0.89 | 40 | 73 | 88 | 97 | 99 |
| Winter | 42 | 67.3 | 37.2 | 0.55 | 0.12 | 0.93 | 31 | 57 | 88 | 93 | 98 |
| Year | 227 | 61.1 | 29.0 | 0.47 | 0.11 | 0.88 | 38 | 66 | 83 | 92 | 95 |
| <u>II</u> | | | | | | | | | | | |
| Spring | 61 | 92.0 | 44.6 | 0.49 | 0.11 | 0.78 | 39 | 61 | 79 | 95 | 98 |
| Summer | 80 | 85.4 | 44.6 | 0.52 | 0.11 | 0.87 | 40 | 66 | 90 | 94 | 98 |
| Fall | 86 | 54.0 | 25.6 | 0.48 | 0.10 | 0.81 | 45 | 66 | 83 | 92 | 97 |
| Winter | 50 | 70.0 | 38.6 | 0.55 | 0.16 | 0.80 | 34 | 56 | 78 | 80 | 84 |
| Year | 277 | 74.3 | 37.6 | 0.51 | 0.12 | 0.85 | 37 | 66 | 81 | 91 | 95 |
| <u>III</u> | | | | | | | | | | | |
| Spring | 81 | 69.3 | 34.1 | 0.50 | 0.13 | 0.89 | 43 | 60 | 80 | 91 | 95 |
| Summer | 98 | 73.4 | 44.3 | 0.59 | 0.14 | 0.88 | 34 | 63 | 77 | 89 | 97 |
| Fall | 105 | 62.7 | 33.5 | 0.55 | 0.13 | 0.89 | 33 | 66 | 85 | 90 | 93 |
| Winter | 99 | 64.0 | 36.0 | 0.56 | 0.15 | 0.88 | 28 | 52 | 77 | 88 | 93 |
| Year | 383 | 67.2 | 37.0 | 0.55 | 0.14 | 0.86 | 31 | 61 | 80 | 89 | 93 |
| <u>IV</u> | | | | | | | | | | | |
| Spring | 134 | 79.9 | 39.3 | 0.51 | 0.11 | 0.91 | 37 | 65 | 85 | 94 | 98 |
| Summer | 125 | 93.2 | 49.7 | 0.55 | 0.13 | 0.88 | 42 | 72 | 85 | 90 | 95 |
| Fall | 125 | 78.5 | 38.1 | 0.51 | 0.10 | 0.85 | 38 | 69 | 89 | 97 | 98 |
| Winter | 98 | 85.7 | 40.2 | 0.49 | 0.10 | 0.90 | 37 | 67 | 86 | 94 | 99 |
| Year | 482 | 84.1 | 41.9 | 0.51 | 0.11 | 0.88 | 37 | 67 | 86 | 94 | 98 |
| <u>V</u> | | | | | | | | | | | |
| Spring | 76 | 91.5 | 44.0 | 0.50 | 0.13 | 0.87 | 21 | 58 | 82 | 89 | 95 |
| Summer | 76 | 87.5 | 41.6 | 0.48 | 0.15 | 0.84 | 20 | 43 | 72 | 82 | 89 |
| Fall | 85 | 78.1 | 34.4 | 0.44 | 0.12 | 0.89 | 28 | 58 | 74 | 82 | 95 |
| Winter | 93 | 67.1 | 37.6 | 0.57 | 0.15 | 0.84 | 38 | 62 | 74 | 86 | 91 |
| Year | 330 | 80.3 | 39.2 | 0.50 | 0.14 | 0.86 | 25 | 49 | 73 | 85 | 93 |
| <u>VI</u> | | | | | | | | | | | |
| Spring | 60 | 81.2 | 36.4 | 0.46 | 0.13 | 0.85 | 27 | 47 | 68 | 88 | 95 |
| Summer | 49 | 76.0 | 36.7 | 0.47 | 0.12 | 0.93 | 31 | 61 | 78 | 88 | 94 |
| Fall | 64 | 91.8 | 38.3 | 0.42 | 0.10 | 0.90 | 27 | 52 | 84 | 95 | 98 |
| Winter | 64 | 87.6 | 40.2 | 0.49 | 0.15 | 0.85 | 42 | 66 | 78 | 83 | 88 |
| Year | 237 | 84.7 | 38.0 | 0.46 | 0.13 | 0.87 | 31 | 57 | 74 | 88 | 92 |
| <u>VII</u> | | | | | | | | | | | |
| Spring | 67 | 93.2 | 41.6 | 0.45 | 0.09 | 0.88 | 33 | 66 | 81 | 96 | 99 |
| Summer | 58 | 85.2 | 40.3 | 0.47 | 0.12 | 0.81 | 26 | 57 | 79 | 93 | 93 |
| Fall | 69 | 78.7 | 37.0 | 0.47 | 0.11 | 0.88 | 23 | 65 | 81 | 94 | 96 |
| Winter | 51 | 85.8 | 45.3 | 0.53 | 0.12 | 0.74 | 31 | 59 | 78 | 92 | 96 |
| Year | 245 | 85.7 | 40.8 | 0.48 | 0.11 | 0.83 | 30 | 63 | 80 | 92 | 95 |

TABLE 4.7 (Cont'd)

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc. ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average PM10/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted PM10 Values in Each Percentage Error Range | | | | |
|------------------------|----------------------|-------------------------------------------------------|------|-----------------------------------|-----------------------------------|----------------------------------------------|-----------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (R_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>IX</u> | | | | | | | | | | | |
| Spring | 142 | 63.7 | 25.1 | 0.40 | 0.13 | 0.84 | 33 | 56 | 76 | 83 | 89 |
| Summer | 127 | 66.7 | 27.3 | 0.40 | 0.15 | 0.73 | 24 | 44 | 66 | 81 | 87 |
| Fall | 125 | 82.3 | 37.1 | 0.41 | 0.11 | 0.97 | 33 | 54 | 70 | 86 | 92 |
| Winter | 154 | 73.1 | 36.5 | 0.50 | 0.16 | 0.88 | 28 | 51 | 69 | 82 | 90 |
| Year | 548 | 71.3 | 31.5 | 0.43 | 0.15 | 0.88 | 29 | 53 | 69 | 82 | 86 |
| <u>X</u> | | | | | | | | | | | |
| Spring | 98 | 55.0 | 22.2 | 0.41 | 0.14 | 0.90 | 31 | 54 | 66 | 76 | 87 |
| Summer | 68 | 76.1 | 30.3 | 0.43 | 0.13 | 0.83 | 24 | 51 | 71 | 81 | 91 |
| Fall | 95 | 68.2 | 31.8 | 0.48 | 0.13 | 0.81 | 27 | 53 | 71 | 82 | 93 |
| Winter | 88 | 68.6 | 32.9 | 0.53 | 0.17 | 0.74 | 18 | 43 | 64 | 80 | 88 |
| Year | 349 | 66.1 | 29.1 | 0.46 | 0.15 | 0.80 | 25 | 49 | 67 | 78 | 87 |
| <u>Nation</u> | | | | | | | | | | | |
| Spring | 778 | 74.7 | 33.9 | 0.46 | 0.13 | 0.88 | 30 | 57 | 75 | 86 | 93 |
| Summer | 734 | 79.2 | 39.0 | 0.49 | 0.15 | 0.82 | 30 | 54 | 72 | 84 | 91 |
| Fall | 827 | 72.1 | 33.7 | 0.47 | 0.12 | 0.89 | 32 | 60 | 78 | 89 | 95 |
| Winter | 739 | 73.9 | 37.7 | 0.53 | 0.15 | 0.83 | 29 | 54 | 74 | 86 | 91 |
| Year | 3,078 | 74.9 | 36.0 | 0.49 | 0.14 | 0.85 | 30 | 56 | 74 | 86 | 92 |

percentage improvement in accuracy obtained by using the regional annual and seasonal average ratios instead of the U.S. annual average ratio is also tabulated for error levels of $\leq 30\%$ and $\leq 50\%$. Data based on national seasonal average ratios are also provided.

The cumulative error distribution data presented in Tables 4.9-4.11 indicate that, as a predictor, the regional seasonal average ratio is generally equal to or slightly better than the regional annual average ratio, which in turn is equal to or slightly better than the U.S. annual average ratio. For the entire data set, the percentage improvements in predictive accuracy resulting from the use of regional annual ratios instead of the U.S. annual average ratio are only 2%, 3%, and 5% for IP15, PM10, and FP, respectively, at an error level of $\leq 30\%$ and 1%, 0, and 6%, respectively, at an error level of $\leq 50\%$. Corresponding percentage improvements in predictive accuracy resulting from the use of regional seasonal ratios are 2%, 4%, and 9% for IP15, PM10, and FP, respectively, at an error level of $\leq 30\%$ and 2%, 2%, and 9%, respectively, at an error level of $\leq 50\%$.

The most improvements in predictive ability resulting from regional and seasonal stratification occur in the following regions:

- For IP15: Regions 2 (at an error level of $\leq 30\%$) and 3.
- For PM10: Regions 9 (at an error level of $\leq 30\%$) and 3, and
- For FP: Regions 2, 3, 4, 6, and 9.

TABLE 4.8 Evaluation of the FP/TSP Average Ratio Model for Data Sets Stratified by Region and Season

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc, ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average FP/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted FP Values in Each Percentage Error Range | | | | |
|------------------------------|----------------------------|----------------------------------------------------------------|------|---------------------------------------|-----------------------------------------|-------------------------------------------------------|------------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (\bar{R}_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>I</u> | | | | | | | | | | | |
| Spring | 59 | 62.3 | 15.0 | 0.24 | 0.08 | 0.71 | 20 | 47 | 68 | 81 | 92 |
| Summer | 53 | 66.2 | 21.2 | 0.31 | 0.13 | 0.73 | 11 | 32 | 53 | 66 | 83 |
| Fall | 73 | 52.8 | 15.3 | 0.28 | 0.09 | 0.81 | 26 | 41 | 60 | 74 | 85 |
| Winter | 42 | 67.3 | 23.5 | 0.34 | 0.12 | 0.85 | 12 | 26 | 57 | 76 | 90 |
| Year | 227 | 61.1 | 18.1 | 0.29 | 0.11 | 0.79 | 21 | 37 | 58 | 74 | 84 |
| <u>II</u> | | | | | | | | | | | |
| Spring | 61 | 92.0 | 26.3 | 0.29 | 0.09 | 0.79 | 28 | 59 | 72 | 89 | 93 |
| Summer | 80 | 85.4 | 29.9 | 0.35 | 0.11 | 0.76 | 19 | 50 | 65 | 76 | 85 |
| Fall | 86 | 54.0 | 17.6 | 0.32 | 0.09 | 0.79 | 28 | 52 | 66 | 84 | 94 |
| Winter | 50 | 70.0 | 26.8 | 0.37 | 0.12 | 0.84 | 24 | 38 | 66 | 78 | 88 |
| Year | 277 | 74.3 | 24.7 | 0.33 | 0.11 | 0.79 | 27 | 47 | 65 | 79 | 90 |
| <u>III</u> | | | | | | | | | | | |
| Spring | 81 | 69.3 | 20.4 | 0.32 | 0.12 | 0.69 | 22 | 49 | 62 | 74 | 83 |
| Summer | 98 | 73.4 | 29.9 | 0.39 | 0.14 | 0.80 | 23 | 43 | 55 | 72 | 87 |
| Fall | 105 | 62.7 | 22.3 | 0.36 | 0.13 | 0.82 | 20 | 38 | 64 | 76 | 82 |
| Winter | 99 | 64.0 | 25.7 | 0.40 | 0.14 | 0.79 | 22 | 47 | 63 | 74 | 84 |
| Year | 383 | 67.2 | 24.7 | 0.37 | 0.14 | 0.75 | 21 | 38 | 56 | 73 | 84 |
| <u>IV</u> | | | | | | | | | | | |
| Spring | 134 | 79.9 | 21.7 | 0.30 | 0.10 | 0.68 | 19 | 40 | 60 | 75 | 89 |
| Summer | 125 | 93.2 | 30.2 | 0.35 | 0.11 | 0.64 | 26 | 50 | 70 | 82 | 89 |
| Fall | 125 | 78.5 | 22.1 | 0.31 | 0.11 | 0.64 | 18 | 38 | 58 | 74 | 86 |
| Winter | 98 | 85.7 | 26.6 | 0.34 | 0.09 | 0.84 | 29 | 55 | 73 | 86 | 93 |
| Year | 482 | 84.1 | 25.0 | 0.32 | 0.10 | 0.69 | 22 | 43 | 65 | 79 | 88 |
| <u>V</u> | | | | | | | | | | | |
| Spring | 76 | 91.5 | 21.8 | 0.26 | 0.11 | 0.65 | 14 | 26 | 51 | 61 | 70 |
| Summer | 76 | 87.5 | 22.8 | 0.27 | 0.15 | 0.50 | 14 | 26 | 43 | 53 | 64 |
| Fall | 85 | 78.1 | 19.3 | 0.26 | 0.11 | 0.74 | 22 | 38 | 49 | 66 | 79 |
| Winter | 93 | 67.1 | 23.6 | 0.37 | 0.15 | 0.57 | 24 | 39 | 51 | 60 | 73 |
| Year | 330 | 80.3 | 21.9 | 0.30 | 0.14 | 0.58 | 12 | 26 | 40 | 58 | 73 |
| <u>VI</u> | | | | | | | | | | | |
| Spring | 60 | 81.2 | 13.2 | 0.18 | 0.09 | 0.56 | 13 | 25 | 33 | 55 | 67 |
| Summer | 49 | 76.0 | 12.4 | 0.18 | 0.07 | 0.65 | 27 | 35 | 59 | 71 | 80 |
| Fall | 64 | 91.8 | 14.6 | 0.18 | 0.07 | 0.67 | 17 | 28 | 41 | 59 | 81 |
| Winter | 64 | 87.6 | 18.3 | 0.25 | 0.15 | 0.32 | 9 | 27 | 44 | 58 | 64 |
| Year | 237 | 84.7 | 14.8 | 0.20 | 0.11 | 0.52 | 14 | 26 | 43 | 57 | 73 |
| <u>VII</u> | | | | | | | | | | | |
| Spring | 67 | 93.2 | 21.6 | 0.23 | 0.10 | 0.62 | 15 | 37 | 52 | 70 | 82 |
| Summer | 58 | 85.2 | 18.7 | 0.22 | 0.09 | 0.54 | 7 | 31 | 45 | 71 | 81 |
| Fall | 69 | 78.7 | 17.5 | 0.24 | 0.11 | 0.53 | 14 | 29 | 43 | 64 | 81 |
| Winter | 51 | 85.8 | 23.9 | 0.29 | 0.11 | 0.50 | 14 | 33 | 51 | 73 | 82 |
| Year | 245 | 85.7 | 20.2 | 0.24 | 0.10 | 0.55 | 17 | 33 | 51 | 66 | 78 |

TABLE 4.8 (Cont'd)

| Federal Region, Season | Number of Data Pairs | Arithmetic Average Conc. ($\mu\text{g}/\text{m}^3$) | | Arithmetic Average FP/TSP Ratio | | Correlation Coefficient between IP15 and TSP | % of Predicted FP Values in Each Percentage Error Range | | | | |
|------------------------------|----------------------------|----------------------------------------------------------------|------|---------------------------------------|-----------------------------------------|-------------------------------------------------------|------------------------------------------------------------|------|------|------|------|
| | | TSP | IP15 | Ratio (\bar{R}_A) | Standard Deviation (σ_R) | | <10% | <20% | <30% | <40% | <50% |
| | | | | | | | | | | | |
| <u>IX</u> | | | | | | | | | | | |
| Spring | 142 | 63.7 | 10.8 | 0.17 | 0.09 | 0.76 | 17 | 42 | 61 | 79 | 87 |
| Summer | 127 | 66.7 | 11.8 | 0.17 | 0.08 | 0.68 | 20 | 42 | 58 | 69 | 80 |
| Fall | 125 | 82.3 | 19.6 | 0.22 | 0.10 | 0.82 | 18 | 34 | 50 | 68 | 78 |
| Winter | 154 | 73.1 | 23.3 | 0.31 | 0.17 | 0.75 | 13 | 31 | 40 | 54 | 69 |
| Year | 548 | 71.3 | 16.6 | 0.22 | 0.13 | 0.73 | 14 | 29 | 43 | 59 | 71 |
| <u>X</u> | | | | | | | | | | | |
| Spring | 98 | 55.0 | 10.8 | 0.21 | 0.07 | 0.67 | 23 | 47 | 65 | 76 | 85 |
| Summer | 68 | 76.1 | 11.2 | 0.17 | 0.08 | 0.58 | 13 | 28 | 49 | 60 | 75 |
| Fall | 95 | 68.2 | 20.2 | 0.31 | 0.14 | 0.65 | 16 | 33 | 41 | 56 | 74 |
| Winter | 88 | 68.6 | 22.1 | 0.38 | 0.16 | 0.56 | 11 | 31 | 44 | 60 | 75 |
| Year | 349 | 66.1 | 16.3 | 0.27 | 0.14 | 0.52 | 16 | 30 | 43 | 57 | 67 |
| <u>Nation</u> | | | | | | | | | | | |
| Spring | 778 | 74.7 | 17.4 | 0.24 | 0.11 | 0.68 | 18 | 35 | 51 | 65 | 77 |
| Summer | 734 | 79.2 | 21.7 | 0.28 | 0.14 | 0.58 | 12 | 25 | 38 | 53 | 67 |
| Fall | 827 | 72.1 | 19.2 | 0.28 | 0.12 | 0.67 | 18 | 34 | 51 | 64 | 75 |
| Winter | 739 | 73.9 | 23.8 | 0.34 | 0.15 | 0.64 | 17 | 33 | 49 | 65 | 78 |
| Year | 3,078 | 74.9 | 20.4 | 0.28 | 0.13 | 0.63 | 15 | 30 | 46 | 60 | 72 |

The correlation coefficient between FP and TSP data is only 0.63 for the entire data set (compared with 0.88 for IP15 and TSP, and 0.85 for PM10 and TSP). Regional stratification caused this coefficient to increase to 0.75-0.79 for Regions 1, 2, and 3, but to decrease to 0.52 for Regions 6 and 10 (see Table 4.8). Even with their improved predictive ability, therefore, the regional seasonal FP/TSP ratios are still a marginal predictor even for the regions in the eastern United States.

In conclusion, regional seasonal average ratios have been shown to be at least equal to or better than the U.S. and regional annual average ratios in terms of their predictive ability with regard to IP15 and PM10 concentrations. Regional seasonal average ratios are not much more complicated to use than the U.S. and regional annual average ratios, and are therefore recommended for use in predicting IP15 and PM10 levels. For FP predictions, however, the regional seasonal average ratio models can be used for only a few regions in the eastern United States, and even there with caution.

TABLE 4.9 Accuracy of Various IP15/TSP Average Ratios in Predicting IP15 Concentrations^a

| Federal Region | IP15/TSP Average Ratio Used for Prediction | % of Predicted IP15 Values in Each Percentage Error Range | | | | | % Improvement in Accuracy of Prediction ^b | |
|-------------------|--------------------------------------------------|--------------------------------------------------------------|-------|-------|-------|-------|---------------------------------------------------------|---------------------------------------|
| | | ≤ 10% | ≤ 20% | ≤ 30% | ≤ 40% | ≤ 50% | IP15 Values with Error of ≤ 30% | IP15 Values with Error of ≤ 50% |
| | | | | | | | | |
| I | U.S. annual | 38 | 71 | 82 | 94 | 97 | | |
| | Regional annual | 41 | 70 | 87 | 92 | 96 | 5 | -1 |
| | Regional seasonal | 42 | 74 | 90 | 95 | 98 | 8 | 1 |
| II | U.S. annual | 39 | 66 | 81 | 91 | 95 | | |
| | Regional annual | 39 | 65 | 82 | 92 | 96 | 1 | 1 |
| | Regional seasonal | 42 | 66 | 83 | 91 | 95 | 2 | 0 |
| III | U.S. annual | 32 | 61 | 77 | 88 | 91 | | |
| | Regional annual | 35 | 64 | 84 | 91 | 96 | 7 | 5 |
| | Regional seasonal | 38 | 64 | 84 | 92 | 97 | 7 | 6 |
| IV | U.S. annual | 38 | 71 | 87 | 93 | 97 | | |
| | Regional annual | 44 | 73 | 87 | 94 | 98 | 0 | 1 |
| | Regional seasonal | 44 | 72 | 87 | 95 | 98 | 0 | 1 |
| V | U.S. annual | 29 | 56 | 78 | 88 | 95 | | |
| | Regional annual | 28 | 59 | 79 | 89 | 95 | 1 | 0 |
| | Regional seasonal | 32 | 60 | 81 | 88 | 97 | 3 | 2 |
| VI | U.S. annual | 31 | 58 | 76 | 87 | 94 | | |
| | Regional annual | 30 | 59 | 76 | 88 | 94 | 0 | 0 |
| | Regional seasonal | 32 | 58 | 76 | 87 | 94 | 0 | 0 |
| VII | U.S. annual | 40 | 67 | 83 | 93 | 97 | | |
| | Regional annual | 39 | 67 | 83 | 93 | 97 | 0 | 0 |
| | Regional seasonal | 37 | 68 | 85 | 93 | 98 | 2 | 1 |
| IX | U.S. annual | 27 | 52 | 71 | 82 | 90 | | |
| | Regional annual | 30 | 53 | 71 | 83 | 88 | 0 | -2 |
| | Regional seasonal | 30 | 54 | 70 | 83 | 91 | -1 | 1 |
| X | U.S. annual | 29 | 55 | 72 | 84 | 89 | | |
| | Regional annual | 26 | 54 | 72 | 82 | 89 | 0 | 0 |
| | Regional seasonal | 28 | 53 | 72 | 82 | 90 | 0 | 1 |
| Nation | U.S. annual | 33 | 61 | 78 | 88 | 93 | | |
| | Regional annual | 35 | 62 | 80 | 89 | 94 | 2 | 1 |
| | U.S. seasonal | 34 | 66 | 81 | 90 | 94 | 3 | 1 |
| | Regional seasonal | 36 | 63 | 80 | 89 | 95 | 2 | 2 |

^aBased on collocated TSP concentration data.

^bOver the accuracy of prediction using the U.S. annual average ratio.

TABLE 4.10 Accuracy of Various PM10/TSP Average Ratios in Predicting PM10 Concentrations^a

| Federal Region | PM10/TSP Average Ratio Used for Prediction | % of Predicted PM10 Values in Each Percentage Error Range | | | | | % Improvement in Accuracy of Prediction ^b | |
|-------------------|--------------------------------------------------|--------------------------------------------------------------|-------------|-------------|-------------|-------------|---------------------------------------------------------|---------------------------------------------|
| | | | | | | | PM10 Values with Error of $\leq 30\%$ | PM10 Values with Error of $\leq 50\%$ |
| | | $\leq 10\%$ | $\leq 20\%$ | $\leq 30\%$ | $\leq 40\%$ | $\leq 50\%$ | | |
| I | U.S. annual | 22 | 37 | 57 | 73 | 84 | | |
| | Regional annual | 21 | 37 | 58 | 74 | 84 | 1 | 0 |
| | Regional seasonal | 19 | 40 | 60 | 74 | 87 | 3 | 3 |
| II | U.S. annual | 20 | 40 | 58 | 71 | 81 | | |
| | Regional annual | 27 | 47 | 65 | 79 | 90 | 7 | 9 |
| | Regional seasonal | 25 | 51 | 67 | 82 | 90 | 9 | 9 |
| III | U.S. annual | 15 | 32 | 48 | 58 | 66 | | |
| | Regional annual | 21 | 38 | 56 | 73 | 84 | 8 | 18 |
| | Regional seasonal | 22 | 44 | 61 | 74 | 84 | 13 | 18 |
| IV | U.S. annual | 19 | 39 | 55 | 71 | 82 | | |
| | Regional annual | 22 | 43 | 65 | 79 | 88 | 10 | 6 |
| | Regional seasonal | 23 | 45 | 65 | 79 | 89 | 10 | 7 |
| V | U.S. annual | 13 | 26 | 42 | 57 | 71 | | |
| | Regional annual | 12 | 26 | 40 | 58 | 73 | -2 | 2 |
| | Regional seasonal | 19 | 33 | 49 | 60 | 72 | 7 | 1 |
| VI | U.S. annual | 14 | 27 | 34 | 47 | 59 | | |
| | Regional annual | 14 | 26 | 43 | 57 | 73 | 9 | 14 |
| | Regional seasonal | 15 | 28 | 43 | 60 | 73 | 9 | 14 |
| VII | U.S. annual | 18 | 33 | 47 | 62 | 77 | | |
| | Regional annual | 17 | 33 | 51 | 66 | 78 | 4 | 1 |
| | Regional seasonal | 13 | 33 | 48 | 69 | 82 | 1 | 5 |
| IX | U.S. annual | 10 | 20 | 34 | 49 | 66 | | |
| | Regional annual | 14 | 29 | 43 | 59 | 71 | 9 | 5 |
| | Regional seasonal | 17 | 37 | 52 | 67 | 78 | 18 | 12 |
| X | U.S. annual | 15 | 27 | 43 | 56 | 66 | | |
| | Regional annual | 16 | 30 | 43 | 57 | 67 | 0 | 1 |
| | Regional seasonal | 16 | 35 | 50 | 63 | 77 | 7 | 11 |
| Nation | U.S. annual | 15 | 30 | 46 | 60 | 72 | | |
| | Regional annual | 18 | 34 | 51 | 67 | 78 | 5 | 6 |
| | U.S. seasonal | 16 | 32 | 42 | 62 | 74 | -4 | 2 |
| | Regional seasonal | 19 | 39 | 55 | 70 | 81 | 9 | 9 |

^aBased on colocated TSP concentration data.

^bOver the accuracy of prediction using the U.S. annual average ratio.

TABLE 4.11 Accuracy of Various FP/TSP Average Ratios in Predicting FP Concentrations^a

| Federal Region | FP/TSP Average Ratio Used for Prediction | % of Predicted FP Values in Each Percentage Error Range | | | | | % Improvement in Accuracy of Prediction ^b | |
|----------------|------------------------------------------|---------------------------------------------------------|-------|-------|-------|-------|------------------------------------------------------|-------------------------------|
| | | ≤ 10% | ≤ 20% | ≤ 30% | ≤ 40% | ≤ 50% | FP Values with Error of ≤ 30% | FP Values with Error of ≤ 50% |
| I | U.S. annual | 34 | 63 | 82 | 93 | 96 | | |
| | Regional annual | 38 | 66 | 83 | 92 | 95 | 1 | -1 |
| | Regional seasonal | 37 | 68 | 87 | 94 | 97 | 5 | 1 |
| II | U.S. annual | 35 | 62 | 79 | 91 | 95 | | |
| | Regional annual | 37 | 66 | 81 | 91 | 95 | 2 | 0 |
| | Regional seasonal | 40 | 63 | 83 | 91 | 95 | 4 | 0 |
| III | U.S. annual | 30 | 55 | 70 | 83 | 89 | | |
| | Regional annual | 31 | 61 | 80 | 89 | 93 | 10 | 4 |
| | Regional seasonal | 34 | 60 | 80 | 90 | 95 | 10 | 6 |
| IV | U.S. annual | 37 | 68 | 84 | 91 | 95 | | |
| | Regional annual | 37 | 67 | 86 | 94 | 98 | 2 | 3 |
| | Regional seasonal | 39 | 68 | 86 | 94 | 98 | 2 | 3 |
| V | U.S. annual | 25 | 49 | 73 | 84 | 92 | | |
| | Regional annual | 25 | 49 | 73 | 85 | 93 | 0 | 1 |
| | Regional seasonal | 27 | 56 | 75 | 85 | 93 | 2 | 1 |
| VI | U.S. annual | 32 | 54 | 76 | 89 | 94 | | |
| | Regional annual | 31 | 57 | 74 | 88 | 92 | -2 | -2 |
| | Regional seasonal | 32 | 56 | 77 | 89 | 94 | 1 | 0 |
| VII | U.S. annual | 31 | 62 | 80 | 92 | 96 | | |
| | Regional annual | 30 | 63 | 80 | 92 | 95 | 0 | -1 |
| | Regional seasonal | 28 | 62 | 80 | 94 | 96 | 0 | 0 |
| IX | U.S. annual | 22 | 48 | 65 | 79 | 90 | | |
| | Regional annual | 29 | 53 | 69 | 82 | 87 | 4 | -3 |
| | Regional seasonal | 30 | 51 | 71 | 83 | 89 | 6 | -1 |
| X | U.S. annual | 27 | 49 | 65 | 80 | 88 | | |
| | Regional annual | 25 | 49 | 67 | 78 | 87 | 2 | -1 |
| | Regional seasonal | 25 | 50 | 68 | 79 | 89 | 3 | 1 |
| Nation | U.S. annual | 30 | 56 | 74 | 86 | 92 | | |
| | Regional annual | 31 | 59 | 77 | 87 | 92 | 3 | 0 |
| | U.S. seasonal | 30 | 56 | 75 | 86 | 93 | 1 | 1 |
| | Regional seasonal | 32 | 59 | 78 | 88 | 94 | 4 | 2 |

^aBased on colocated TSP concentration data.^bOver the accuracy of prediction using the U.S. annual average ratio.

5 POTENTIAL EFFECTS OF POSSIBLE NEW SIZE-SPECIFIC PARTICULATE NAAQS ON NONATTAINMENT PROBLEMS

The nonattainment potential with respect to possible new size-specific particulate NAAQS was assessed on the basis of two data sets. The first was the IPM monitoring network data from the 52 sites screened for use in this study. To determine potential nonattainments, calculated PM₁₀ concentrations were compared with various PM₁₀ standards currently under consideration, and measured FP concentrations were compared with an FP standard discussed at one time. The second data set consisted of ambient TSP data from over 3600 monitoring sites throughout the country for 1982. Concentrations of PM₁₀ were estimated using the U.S. annual and regional annual average ratio models derived in this study, and then were compared with the PM₁₀ standards currently under consideration.

Watson et al.⁸ noted two views on the use of IP₁₅ values predicted from average ratio models in determining compliance with ambient air quality standards:

1. If the confidence interval around the predicted IP₁₅ value is comparable to the differences among nearby sampling sites assessing ambient concentrations in the same portion of a neighborhood, the uncertainty of an average ratio model can be considered to be comparable to the sampling precision. Thus, there would be no significant difference between the TSP-derived IP₁₅ concentration and one that is actually measured. Therefore, the predicted concentration can be used for comparison against a standard in the same way as an ambient measurement.
2. A more restrictive but safer approach would be to add some number of standard deviations to the TSP-derived IP₁₅ concentration, and to compare this value to the standard with a corresponding confidence level.

The first of the above two approaches was taken in using the 1982 ambient particulate data from the Storage and Retrieval of Aerometric Data (SAROAD) data base to assess potential nonattainment problems respect to possible NAAQS for PM₁₀.

5.1 ASSESSMENT BASED ON IPM MONITORING NETWORK DATA

The annual average PM₁₀ concentration (actually a 2-yr average for 1980-1981) and the second highest 24-hr PM₁₀ concentration for the same 2-yr period are listed in Table A.1 for each of the 52 monitoring sites providing data. The range of values in the table is 13-69 $\mu\text{g}/\text{m}^3$ for the 2-yr average and 28-142 $\mu\text{g}/\text{m}^3$ for the 24-hr level.

If the annual standard for ambient PM₁₀ concentrations is established at 70 $\mu\text{g}/\text{m}^3$ (which is 5 $\mu\text{g}/\text{m}^3$ higher than the upper end of the range currently under consideration), and if the maximum 24-hr standard is set at 150 $\mu\text{g}/\text{m}^3$ (the lower end of

the range under consideration), all 52 IPM monitoring sites are likely to be in nonattainment. If the annual standard is set at $50 \mu\text{g}/\text{m}^3$ (the lower end of the range currently under consideration), at least 8 of the 52 sites are likely to be in nonattainment in either 1980 or 1981. These sites are distributed throughout the country except in Regions 1, 7, and 10.

The maximum annual and seasonal average FP concentrations* are also listed in Table A.1 for each monitoring site. The annual averages for Regions 2, 3, and 4 are at the upper end of the $8\text{--}25 \mu\text{g}/\text{m}^3$ range that was suggested as a possible seasonal and spatial average by EPA at one time for the FP ambient standard. Seasonal peaks exceed $25 \mu\text{g}/\text{m}^3$ by substantial margins in many parts of the country.

5.2 ASSESSMENT BASED ON 1982 U.S. AMBIENT DATA

Data on TSP concentrations from the ambient air quality monitoring stations operated throughout the country by local, state, and federal networks during 1982⁷ are listed in Table A.1 for those stations reporting annual arithmetic average concentrations greater than $75 \mu\text{g}/\text{m}^3$ or second highest 24-hr concentrations greater than $260 \mu\text{g}/\text{m}^3$. Concentrations of PM₁₀ were estimated from the U.S. and regional annual average PM₁₀/TSP ratios, and those concentrations exceeding the lowest PM₁₀ primary standards currently under consideration ($50 \mu\text{g}/\text{m}^3$ for the annual average and $150 \mu\text{g}/\text{m}^3$ for the 24-hr maximum) are also listed. The annual geometric average TSP concentrations for the screened stations are also listed, in order to determine nonattainment at the county level with respect to the current NAAQS for TSP.

A count was made in Table 5.2 of the number of counties exceeding (1) the current TSP standards and (2) various proposed PM₁₀ standards. These county totals are listed by region in Tables 5.1 and 5.2 for the annual and maximum 24-hr standards for TSP, respectively. In 1982, the number of nonattainment counties was 57 with respect to the current annual primary standard for TSP and 53 with respect to the maximum 24-hr standard. Of these counties, 20 were in violation of both standards, leaving 90 counties altogether in nonattainment of the current primary NAAQS for TSP.

If new PM₁₀ primary standards were adopted at the lowest ends of the ranges currently under consideration ($50 \mu\text{g}/\text{m}^3$ for the annual standard and $150 \mu\text{g}/\text{m}^3$ for the maximum 24-hr standard), then the number of counties likely to be in nonattainment would be reduced to 29 under the new annual standard and 32 under the new maximum 24-hr standard -- that is, when PM₁₀ levels are calculated from the U.S. annual average PM₁₀/TSP ratio. These numbers would be further reduced to 26 and 31, respectively, when PM₁₀ levels are calculated from the regional annual average PM₁₀/TSP ratios. The reason for these different results is that there are two additional nonattainment counties in the eastern United States where the regional annual PM₁₀/TSP ratio is greater than

*The annual average is actually a 2-yr average for 1980 and 1981. Each seasonal average represents two seasons, one in 1980 and the other in 1981; for example, the winter average is based on data from both winters in that time period.

TABLE 5.1 Actual and Potential Number of Nonattainment Counties with Respect to Current and Proposed Annual Average NAAQS for Particulates

| Federal Region | Counties Violating TSP Standard in 1982 ^a | Counties Potentially Violating Proposed PM10 Standards, ^b Based on U.S. Average PM10/TSP Ratio ^c | | | | Counties Potentially Violating Proposed PM10 Standards, ^b Based on Regional Average PM10/TSP Ratios ^c | | | |
|-------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|
| | | 50 $\mu\text{g}/\text{m}^3$ | 55 $\mu\text{g}/\text{m}^3$ | 60 $\mu\text{g}/\text{m}^3$ | 65 $\mu\text{g}/\text{m}^3$ | 50 $\mu\text{g}/\text{m}^3$ | 55 $\mu\text{g}/\text{m}^3$ | 60 $\mu\text{g}/\text{m}^3$ | 65 $\mu\text{g}/\text{m}^3$ |
| I | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| II ^d | 3 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| III | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IV | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| V | 12 | 6 | 4 | 3 | 1 | 7 | 5 | 3 | 1 |
| VI | 9 | 3 | 2 | 2 | 1 | 3 | 2 | 1 | 1 |
| VII | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| VIII ^e | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| IX ^f | 13 | 10 | 5 | 3 | 2 | 5 | 2 | 2 | 2 |
| X | 7 | 5 | 4 | 2 | 1 | 5 | 2 | 1 | 0 |
| Total | 57 | 29 | 18 | 12 | 7 | 26 | 14 | 9 | 5 |

^aStandard defined as 75 $\mu\text{g}/\text{m}^3$ (geometric average).

^bAll four defined as arithmetic averages.

^cSince monitored county-level data on PM10 concentrations are not available, violations were assessed by estimating PM10 concentrations for each county using an average ratio model for PM10/TSP, and then comparing those results with the average PM10/TSP ratio first for the nation, then for the region in which the county is located.

^dExcludes Puerto Rico data.

^eThe U.S. annual average PM10/TSP ratio was used for calculating all Region VIII data.

^fExcludes Guam data.

the U.S. annual ratio, and five fewer nonattainment counties in the western United States where it is smaller.

If the new PM10 standards are established at the upper ends of the ranges currently under consideration (65 $\mu\text{g}/\text{m}^3$ for the annual standard and 250 $\mu\text{g}/\text{m}^3$ for the maximum 24-hr standard), then the likely number of nonattainment counties would be further reduced to 7 with respect to the new annual standard and 5 with respect to the new maximum 24-hr standard, i.e., when PM10 levels are calculated from the U.S. annual average PM10/TSP ratio. The number of nonattainment counties with regard to both

TABLE 5.2 Actual and Potential Number of Nonattainment Counties with Respect to Current and Proposed Maximum 24-hr NAAQS for Particulates

| Federal Region | Counties Violating TSP Standard in 1982 ^a | Counties Potentially Violating Proposed PM10 Standards, Based on U.S. Average PM10/TSP Ratio ^b | | | Counties Potentially Violating Proposed PM10 Standards, Based on Regional Average PM10/TSP Ratios ^b | | |
|-------------------|------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------|
| | | 150 $\mu\text{g}/\text{m}^3$ | 200 $\mu\text{g}/\text{m}^3$ | 250 $\mu\text{g}/\text{m}^3$ | 150 $\mu\text{g}/\text{m}^3$ | 200 $\mu\text{g}/\text{m}^3$ | 250 $\mu\text{g}/\text{m}^3$ |
| I 4 | 2 | 1 | 1 | 2 | 1 | 1 | |
| II ^c | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| III | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IV | 3 | 1 | 0 | 0 | 1 | 0 | 0 |
| V 11 | 5 | 3 | 1 | 5 | 3 | 1 | |
| VI | 8 | 5 | 2 | 0 | 4 | 1 | 0 |
| VII | 2 | 1 | 0 | 0 | 1 | 0 | 0 |
| VIII ^d | 12 | 7 | 2 | 1 | 7 | 2 | 1 |
| IX ^e | 6 | 5 | 4 | 2 | 5 | 2 | 2 |
| X 6 | 5 | 1 | 0 | 5 | 1 | 0 | |
| Total | 53 | 32 | 13 | 5 | 31 | 10 | 5 |

^aStandard defined as 260 $\mu\text{g}/\text{m}^3$, not to be exceeded more than once per year.

^bSince monitored county-level data on PM10 concentrations are not available, violations were assessed by estimating PM10 concentrations for each county using an average PM10/TSP ratio model, and then comparing the county results with either the national average PM10/TSP ratio or the average for the region in which the county is located.

^cExcludes Puerto Rico data.

^dThe U.S. annual average PM10/TSP ratio was used for calculating all Region VIII data.

^eExcludes Guam data.

standards would be 5 when PM10 levels are based on the regional annual average PM10/TSP ratios. This difference again is caused by variations in the regional annual average ratios with respect to the U.S. annual average ratio.

In assessing the likelihood of nonattainment with respect to a new maximum 24-hr PM10 standard, a regional seasonal PM10/TSP ratio would be more specific than a regional annual ratio in estimating 24-hr PM10 concentration levels from the routinely available TSP concentration data. Although that was not done in this study, complete raw 24-hr TSP concentration data can be obtained from EPA for such an assessment.

6 SUMMARY AND CONCLUSIONS

As stated earlier, in anticipation of size-specific NAAQS for particulates, EPA began in 1979 to establish a nationwide IPM monitoring network primarily in the urban areas of selected airsheds. Each monitoring site in the network measures concentrations of IP15 and FP ($< 15 \mu\text{m}$ and $< 2.5 \mu\text{m}$ in aerodynamic diameter, respectively) using a dichotomous sampler. Concentrations of TSP are measured with a collocated high-volume sampler. However, the scale of the network is quite limited, consisting of some 160 stations established by the end of 1981 (compared with over 3,600 stations measuring TSP levels in 1982).

Because of this limitation in spatial coverage, models are needed for predicting size-specific particulate concentrations from the routinely available TSP data. Simple arithmetic average ratio models have recently been developed. However, due to limited data availability, only a nationwide average ratio model for predicting IP15 was developed, and any refinement of the model by stratifying the IPM data base according to parameters that cause significant variations in the IP15/TSP ratio was not possible. Furthermore, derivation of an arithmetic average ratio model for predicting PM10 (particulate matter with an aerodynamic diameter $< 10 \mu\text{m}$) from TSP data was non-existent in early 1982 except for one site.

In this study, an expanded IPM data base (covering mid-1979 to the end of 1981 at some 160 IPM monitoring stations) was examined and screened to determine whether data stratification might improve the accuracy and reliability of the average particulate ratio models. In order to prevent errors that might be introduced by the use of the TSP data obtained in 1979 at the IPM monitoring stations using a quartz fiber filter medium (which was different from that used in the routine TSP measurements), the 1979 IPM monitoring data were eliminated. Data from IPM monitoring stations without adequate seasonal representation were also eliminated so that seasonal effects could be properly reflected in the models to be derived from the data base.

The size cut-point for defining the upper end of the inhalable particulate matter was initially set at $15 \mu\text{m}$ in aerodynamic diameter. However, it was reduced to $10 \mu\text{m}$ in 1981 subsequent to the deployment of most of the dichotomous samplers designed for the $15\text{-}\mu\text{m}$ upper size cut-point. Therefore, the expanded data base (from mid-1979 to the end of 1981) did not contain any routinely monitored PM10 data. In order to derive PM10 concentration data from the IP15, FP, and collocated TSP concentration data, the typical bimodal distribution of ambient particulate mass with respect to particle diameter was approximated to be a log-normal distribution. The monitored IP15, FP, and TSP concentration data, plus the calculated PM10 concentration data, constituted the data base for derivation of the prediction models.

The geographical and seasonal variations in the average levels of various size-specific particulate concentrations (obtained from the screened IPM data base) were examined in terms of coarse mode particles ($> 2.5 \mu\text{m}$ in aerodynamic diameter), which are generated from mechanical processes such as grinding and wind erosion, and FP (fine mode particles $< 2.5 \mu\text{m}$), which originate from the nuclei mode by condensation of

materials produced during combustion or atmospheric transformation. This examination suggests the following:

1. The average concentration levels of TSP, IP15, and PM10 consisting all or partly of coarse mode particles are in general highest in the mid-section of the United States, and lowest in the New England and West Coast regions. In comparison, the average concentration levels of FP are generally highest in the eastern United States.
2. The processes that generate coarse or fine mode particles appear to be strongly dependent on season. Average coarse mode particle concentrations are highest during spring and summer and lowest in winter, while those of FP are highest during winter and summer. The seasonal pattern of regional average TSP concentrations is largely determined by that of coarse mode particle levels, which contribute more mass to TSP than FP. On the other hand, the seasonal pattern of regional IP15 and PM10 concentrations is largely determined by that of FP due to the combined effects of the FP's substantial mass contribution as well as its more pronounced seasonal variability.

Statistical tests suggest that stratification of the screened IPM data base by certain parameters such as federal region, season, and monitoring site type produces significantly different groups of average IP15/TSP, PM10/TSP, and FP/TSP ratios. In this study, average ratio models for predicting IP15, PM10, and FP from the routinely available TSP data were derived from the screened IPM data base stratified by federal region, season, and both. The models derived were evaluated to determine whether such stratification would result in improved predictive ability.

The U.S. annual average particulate ratio models were found to be reasonably good predictors for estimating IP15 and PM10 concentrations from the routinely available TSP data, but not FP concentrations. This finding is in agreement with those of other investigators. Stratification by certain parameters appears to improve the predictive ability of these models to a certain extent. In general, with regard to predictive ability, seasonal average ratio models are equal to or slightly better than regional annual average ratio models, which in turn are equal to or slightly better than the U.S. annual average ratio model. However, the regional seasonal average ratio models are still marginal predictors of FP even for the eastern United States, where their predictive ability is substantially improved by data stratification according to federal region and season.

If the new PM10 primary NAAQS currently under consideration ($50-65 \mu\text{g}/\text{m}^3$ for the annual arithmetic average and $150-250 \mu\text{g}/\text{m}^3$ for the maximum 24-hr standard) were promulgated, nonattainment problems would likely be reduced substantially. The number of counties in violation of the current primary NAAQS for TSP in 1982 was 57 with respect to the annual geometric average ($75 \mu\text{g}/\text{m}^3$) and 53 with respect to the maximum 24-hr standard ($260 \mu\text{g}/\text{m}^3$). If the new PM10 primary standards were adopted at the

lowest ends of the ranges currently under consideration ($50 \mu\text{g}/\text{m}^3$ for the annual average and $150 \mu\text{g}/\text{m}^3$ for the maximum 24-hr standard), then the number of likely nonattainment counties would be reduced to 29 with respect to the annual average and 32 with respect to the 24-hr standard, when PM10 concentrations are based on the U.S. annual average PM10/TSP ratio. These county figures would be further reduced to 26 and 31, respectively, when PM10 concentrations are based on the regional annual average PM10/TSP ratios. If the highest PM10 primary standards under consideration were adopted ($65 \mu\text{g}/\text{m}^3$ for the annual average and $250 \mu\text{g}/\text{m}^3$ for the maximum 24-hr standard), then the number of likely nonattainment counties would be reduced further to 7 and 5, respectively, when PM10 concentrations are based on the U.S. annual average PM10/TSP ratio, and to 5 with respect to both standards when PM10 concentrations are based on the regional annual average PM10/TSP ratios.

REFERENCES

1. *National Primary and Secondary Ambient Air Quality Standards* (40 CFR, Part 50), Federal Register, 36:22384 (Nov. 21, 1971).
2. *National Primary and Secondary Ambient Air Quality Standards* (40 CFR, Part 50), Appendix B: *Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method)*, Fed. Reg., 47:54899 (Dec. 6, 1982).
3. Environmental Reporter, *Current Developments*, p. 1047 (Oct. 21, 1983).
4. *Review of the National Ambient Air Quality Standards for Particulate Matter: Assessment of Scientific and Technical Information*, U.S. Environmental Protection Agency Report EPA-450/5-82-001 (Jan. 1982).
5. Miller, F.J., et al., *Size Considerations for Establishing a Standard for Inhalable Particles*, J. Air Pollution Control Assn., 29:610 (1979).
6. International Standards Organization, *Recommendation on Size Definition for Particle Sampling*, American Industrial Hygiene Assn. J., 42:A64 (1981).
7. *Air Quality Data: 1982 Annual Statistics*, U.S. Environmental Protection Agency Report EPA-450/4-83-016 (Sept. 1983).
8. Watson, J.G., J.C. Chow, and J. Shah, *Analysis of Inhalable and Fine Particulate Matter Measurements*, U.S. Environmental Protection Agency Report EPA-450/4-81-035 (Dec. 1981).
9. Rodes, C.E., and J.C. Suggs, *EPA's Inhalable Particulate Monitoring Activities in Support of a Possible Size-Specific Ambient Standard*, presented at 75th Annual Meeting of Air Pollution Control Assn., New Orleans (June 20-25, 1982).
10. Rote, D., Argonne National Laboratory, unpublished information (Sept. 1981).
11. Trijonis, J., et al., *Analysis of the St. Louis RAMS Ambient Particulate Data*, U.S. Environmental Protection Agency Report EPA-450/4-80-006A (Feb. 1980).
12. Loo, B.W., and J.M. Jaklevic, *An Evaluation of the ERC Virtual Impactor*, Lawrence Berkeley Laboratory Report LBL-2468 (1974).
13. Miller, I., and J.E. Freund, *Probability and Statistics for Engineers*, Prentice-Hall, Inc., Englewood Cliffs, N.J. (1965).
14. Miller, R.G., Jr., *Simultaneous Statistical Inference*, 2nd Ed., Springer-Verlag, New York (1981).

APPENDIX:
PARTICULATE AIR QUALITY DATA

TABLE A.1 IPM Monitoring Stations Meeting the Seasonal Data Requirements for 1980-1981

| Monitoring Station Identification Data | | | Number of Data Sets Available | | | | | Particulate Concentrations ($\mu\text{g}/\text{m}^3$) | | | | | |
|----------------------------------------|--------------------------|----------------------|-------------------------------|--------|------|--------|-------|---------------------------------------------------------|------|------------------------------------------|-------------------------|------|--|
| | | | | | | | | Annual Average | | FP Maximum Seasonal Average ^b | 2nd Highest 24-hr Level | | |
| | | | | | | | | TSP | PM10 | | TSP ^{b,c} | PM10 | |
| Location | SAROAD Code ^a | Type | Spring | Summer | Fall | Winter | Total | | | | | | |
| Region I | | | | | | | | | | | | | |
| Massachusetts | | | | | | | | | | | | | |
| Boston | 220240012A07 | urban commercial | 17 | 15 | 23 | 14 | 69 | 63 | 29 | 22 (W) | 124 (W) | 69 | |
| Boston | 220240013A07 | urban commercial | 19 | 17 | 19 | 10 | 65 | 57 | 28 | 20 (W) | 97 (Su) | 65 | |
| Connecticut | | | | | | | | | | | | | |
| Hartford | 070420003A07 | urban commercial | 23 | 21 | 31 | 18 | 93 | 62 | 30 | 27 (W) | 147 (W) | 98 | |
| Total or average | | | 59 | 53 | 73 | 42 | 227 | 61 | 29 | 18 | | | |
| Region II | | | | | | | | | | | | | |
| New York | | | | | | | | | | | | | |
| Buffalo | 330660003A07 | urban industrial | 11 | 14 | 11 | 10 | 46 | 98 | 57 | 44 (W) | 160 (Su) | 102 | |
| Buffalo | 330660010A07 | urban industrial | 15 | 16 | 12 | 13 | 56 | 101 | 41 | 32 (Su) | 163 (Su) | 85 | |
| New York | 334680005A07 | urban commercial | 11 | 12 | 15 | 5 | 43 | 63 | 33 | 27 (Su) | 113 (Sp) | 59 | |
| Brooklyn | 334680011A07 | urban industrial | 15 | 19 | 21 | 12 | 67 | 71 | 39 | 28 (Su) | 146 (W) | 75 | |
| New Jersey | | | | | | | | | | | | | |
| Livingston | 311380001A07 | suburban residential | 9 | 19 | 27 | 10 | 65 | 46 | 23 | 22 (Su) | 85 (Sp) | 54 | |
| Total or average | | | 61 | 80 | 86 | 50 | 277 | 74 | 38 | 25 | | | |
| Region III | | | | | | | | | | | | | |
| Pennsylvania | | | | | | | | | | | | | |
| Philadelphia | 397140024A07 | suburban residential | 15 | 27 | 22 | 26 | 90 | 54 | 35 | 30 (Su) | 137 (Su) | 86 | |
| Pittsburgh | 397260021A07 | suburban residential | 13 | 13 | 6 | 12 | 44 | 111 | 63 | 61 (F) | 229 (Sp) | 119 | |
| Maryland | | | | | | | | | | | | | |
| Baltimore | 210120009A07 | suburban residential | 14 | 13 | 13 | 11 | 51 | 60 | 32 | 26 (Su) | 114 (Su) | 70 | |
| District of Columbia | 090020017A07 | urban commercial | 16 | 17 | 12 | 15 | 60 | 76 | 39 | 34 (Su) | 128 (Sp) | 89 | |
| Virginia | | | | | | | | | | | | | |
| Hopewell | 481560002A07 | suburban industrial | 11 | 14 | 27 | 19 | 71 | 73 | 35 | 26 (W) | 134 (Sp) | 70 | |
| Reston | 482630001A07 | other | 12 | 14 | 25 | 16 | 67 | 47 | 27 | 23 (Su) | 79 (Su) | 58 | |
| Total or average | | | 81 | 98 | 105 | 99 | 383 | 67 | 37 | 25 | | | |

TABLE A.1 (Cont'd)

| Monitoring Station Identification Data | | | | | | | | Particulate Concentrations (µg/m ³) | | | | |
|----------------------------------------|--------------------------|----------------------|--------|--------|------|--------|-------|-------------------------------------------------|------|------------------------------------------|-------------------------|------|
| | | | | | | | | Annual Average | | FP Maximum Seasonal Average ^b | 2nd Highest 24-hr Level | |
| Location | SAROAD Code ^a | Type | Spring | Summer | Fall | Winter | Total | TSP | PM10 | | TSP ^{b,c} | PM10 |
| Region IV | | | | | | | | | | | | |
| Georgia | | | | | | | | | | | | |
| Atlanta | 110200001A07 | urban commercial | 7 | 19 | 8 | 5 | 39 | 61 | 35 | 27 (Su) | 117 (Su) | 69 |
| Atlanta | 110200039A07 | urban commercial | 10 | 14 | 10 | 5 | 39 | 78 | 38 | 29 (Su) | 138 (F) | 69 |
| Alabama | | | | | | | | | | | | |
| Birmingham | 010380003A07 | urban commercial | 18 | 13 | 14 | 17 | 62 | 76 | 41 | 31 (Su) | 190 (F) | 78 |
| Birmingham | 010380023A07 | urban industrial | 9 | 17 | 29 | 15 | 70 | 108 | 52 | 35 (Su) | 285 (Su) | 131 |
| Birmingham | 010380026A07 | suburban residential | 25 | 13 | 12 | 6 | 56 | 101 | 49 | 34 (W) | 195 (Su) | 78 |
| Center Point | 010570001A07 | suburban residential | 15 | 23 | 22 | 14 | 74 | 61 | 37 | 29 (Su) | 108 (Sp) | 67 |
| Mt. Brook | 012540001A07 | suburban residential | 26 | 14 | 15 | 17 | 72 | 54 | 26 | 27 (Su) | 91 (Su) | 49 |
| Tarrant City | 013200001A07 | suburban industrial | 24 | 12 | 15 | 19 | 70 | 126 | 54 | 35 (Su) | 211 (Su) | 92 |
| Total or average | | | 134 | 125 | 125 | 98 | 482 | 84 | 42 | 25 | | |
| Region V | | | | | | | | | | | | |
| Ohio | | | | | | | | | | | | |
| Akron | 360060014A07 | urban industrial | 13 | 15 | 13 | 24 | 65 | 68 | 41 | 29 (Su) | 117 (Su) | 76 |
| Cincinnati | 361220020A07 | suburban residential | 14 | 12 | 10 | 10 | 46 | 60 | 36 | 33 (Su) | 116 (F) | 76 |
| Cleveland | 361300013A07 | urban industrial | 10 | 8 | 15 | 12 | 45 | 133 | 62 | 36 (Sp) | 239 (Sp) | 116 |
| Youngstown | 367760002A07 | urban industrial | 9 | 14 | 22 | 15 | 60 | 94 | 39 | 25 (Sp) | 233 (Sp) | 97 |
| Minnesota | | | | | | | | | | | | |
| Minneapolis | 242260049A07 | urban residential | 14 | 16 | 12 | 18 | 60 | 55 | 26 | 18 (W) | 120 (Sp) | 45 |
| Minneapolis | 242260051A07 | urban commercial | 16 | 11 | 13 | 14 | 54 | 80 | 35 | 24 (W) | 183 (Sp) | 70 |
| Total or average | | | 76 | 76 | 85 | 93 | 330 | 80 | 39 | 22 | | |
| Region VI | | | | | | | | | | | | |
| Texas | | | | | | | | | | | | |
| Dallas | 451310050A07 | urban commercial | 18 | 13 | 18 | 24 | 73 | 73 | 32 | 22 (Sp) | 224 (Sp) | 72 |
| Clint | 451710004A07 | agricultural | 23 | 20 | 17 | 24 | 84 | 76 | 39 | 15 (W) | 210 (W) | 93 |
| New Mexico | | | | | | | | | | | | |
| Albuquerque | 320040001A07 | rural commercial | 8 | 8 | 15 | 5 | 36 | 87 | 33 | 34 (W) | 205 (F) | 88 |
| Bayard | 320090001A07 | rural commercial | 11 | 8 | 14 | 11 | 44 | 121 | 51 | 14 (F) | 192 (F) | 98 |
| Total or average | | | 60 | 49 | 64 | 64 | 237 | 85 | 38 | 15 | | |

TABLE A.1 (Cont'd)

| Monitoring Station Identification Data | | | Number of Data Sets Available | | | | | Particulate Concentrations ($\mu\text{g}/\text{m}^3$) | | | | | |
|----------------------------------------|--------------------------|----------------------|-------------------------------|--------|------|--------|-------|---------------------------------------------------------|------|------------------------------------------|-------------------------|--------------------|------|
| | | | | | | | | Annual Average | | FP Maximum Seasonal Average ^b | 2nd Highest 24-hr Level | | |
| Location | SAROAD Code ^a | Type | Spring | Summer | Fall | Winter | Total | TSP | PM10 | | | TSP ^{b,c} | PM10 |
| Region VII | | | | | | | | | | | | | |
| Missouri | | | | | | | | | | | | | |
| Afton | 260030001A07 | suburban commercial | 12 | 14 | 7 | 9 | 42 | 69 | 38 | 24 (Su) | 118 (Su) | 72 | |
| Kansas City | 262380002A07 | urban commercial | 19 | 11 | 29 | 16 | 75 | 90 | 41 | 23 (W) | 158 (Sp) | 77 | |
| Iowa | | | | | | | | | | | | | |
| Marshalltown | 162500003A07 | urban commercial | 9 | 8 | 23 | 8 | 48 | 74 | 35 | 18 (W) | 120 (F) | 59 | |
| Kansas | | | | | | | | | | | | | |
| Kansas City | 171800011A07 | urban industrial | 27 | 25 | 10 | 18 | 80 | 98 | 46 | 29 (Sp) | 197 (F) | 102 | |
| Total or average | | | | 67 | 58 | 69 | 51 | 245 | 86 | 41 | 20 | | |
| Region IX | | | | | | | | | | | | | |
| Arizona | | | | | | | | | | | | | |
| Phoenix | 030440006A07 | other | 7 | 8 | 18 | 13 | 46 | 39 | 17 | 9 (W) | 73 (F) | 35 | |
| Phoenix | 030600002A07 | urban residential | 6 | 9 | 9 | 11 | 35 | 127 | 69 | 35 (W) | 226 (F) | 120 | |
| Nevada | | | | | | | | | | | | | |
| Winnemucca | 290580001A07 | urban commercial | 17 | 20 | 11 | 5 | 53 | 55 | 23 | 10 (F) | 180 (Su) | 80 | |
| California | | | | | | | | | | | | | |
| Azusa | 050500002A07 | suburban residential | 10 | 7 | 9 | 16 | 42 | 124 | 52 | 40 (F) | 264 (F) | 104 | |
| Five Points | 052820002A07 | agricultural | 18 | 12 | 5 | 19 | 54 | 77 | 31 | 32 (F) | 297 (F) | 142 | |
| Los Angeles | 054180103A07 | suburban commercial | 13 | 8 | 11 | 16 | 48 | 84 | 43 | 38 (W) | 149 (W) | 95 | |
| Richmond | 056300003A07 | suburban commercial | 13 | 11 | 15 | 18 | 57 | 57 | 24 | 23 (W) | 124 (F) | 66 | |
| San Francisco | 056860003A07 | urban commercial | 11 | 23 | 24 | 22 | 80 | 60 | 27 | 25 (W) | 154 (F) | 83 | |
| San Jose | 056980004A07 | urban commercial | 29 | 16 | 11 | 20 | 76 | 85 | 34 | 38 (F) | 223 (F) | 108 | |
| Hawaii | | | | | | | | | | | | | |
| Honolulu | 120370004A07 | suburban residential | 18 | 13 | 12 | 14 | 57 | 35 | 13 | 7 (W) | 56 (W) | 28 | |
| Total or average | | | 142 | 127 | 125 | 154 | 548 | 71 | 32 | 17 | | | |

TABLE A.1 (Cont'd)

| Monitoring Station Identification Data | | | | | | | | Particulate Concentrations (ug/m ³) | | | | |
|----------------------------------------|--------------------------|----------------------|--------|--------|------|--------|-------|-------------------------------------------------|------|------------------------------------------|-------------------------|------|
| | | | | | | | | Annual Average | | FP Maximum Seasonal Average ^b | 2nd Highest 24-hr Level | |
| Location | SAROAD Code ^a | Type | Spring | Summer | Fall | Winter | Total | TSP | PM10 | | TSP ^{b,c} | PM10 |
| Region X | | | | | | | | | | | | |
| Idaho | | | | | | | | | | | | |
| Boise | 130220003A07 | urban commercial | 5 | 5 | 21 | 10 | 41 | 84 | 35 | 26 (W) | 173 (F) | 75 |
| Washington | | | | | | | | | | | | |
| S. Seattle | 491840057A07 | suburban industrial | 15 | 12 | 14 | 15 | 56 | 102 | 34 | 23 (W) | 298 (F) | 74 |
| Seattle | 491840073A07 | suburban residential | 29 | 15 | 11 | 20 | 75 | 43 | 19 | 19 (F) | 103 (F) | 47 |
| Oregon | | | | | | | | | | | | |
| Portland | 380500104A07 | agricultural | 12 | 10 | 8 | 12 | 42 | 45 | 23 | 18 (W) | 114 (Su) | 54 |
| Eugene | 380560013A07 | urban commercial | 15 | 14 | 28 | 17 | 74 | 52 | 27 | 22 (W) | 112 (F) | 73 |
| Portland | 381460015A07 | urban commercial | 22 | 12 | 13 | 14 | 61 | 82 | 40 | 27 (F) | 214 (Sp) | 90 |
| Total or average | | | 98 | 68 | 95 | 88 | 349 | 66 | 29 | 19 | | |
| National total | | | 734 | 827 | 739 | 3,078 | 75 | 36 | 20 | | | |
| or average | | | | | | | | | | | | |

^aCode assigned by EPA to each monitoring station reporting data to the Storage and Retrieval of Aerometric Data (SAROAD) system.

^bSp = spring, Su = summer, F = fall, and W = winter.

^cBased on all TSP data collected at each site.

TABLE A.2 Concentrations of TSP in Counties Violating NAAQS for TSP in 1982^a and the Estimated PM₁₀ Concentrations in Those Counties

| Monitoring Station with the Highest Concentration in Its County | | Annual Arithmetic Average TSP Concentration ($\mu\text{g}/\text{m}^3$) | | Annual Arithmetic Average PM ₁₀ Concentration ^c ($\mu\text{g}/\text{m}^3$) | | Second Highest 24-hr Concentration ($\mu\text{g}/\text{m}^3$) | | |
|-----------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------------|
| | | | | | | PM ₁₀ ^c | | |
| | | Geo- metric | Arith- metic | Based On U.S. Average PM ₁₀ /TSP Ratio | Based on Regional Average PM ₁₀ /TSP Ratio | TSP | Based On U.S. Average PM ₁₀ /TSP Ratio | Based on Regional Average PM ₁₀ /TSP Ratio |
| Location | SAROAD Code ^b | | | | | | | |
| <u>Region I</u> | | | | | | | | |
| Maine | | | | | | | | |
| Franklin | 200530006J02 | - | - | | | 576 | 282 | 271 |
| Penobscot | 200640004J02 | - | - | | | 289 | | |
| Aroostook | 200720003J02 | 47 | 57 | | | 295 | | |
| Massachusetts | | | | | | | | |
| Suffolk | 220240024F01 | 70 | 78 | | | 145 | | |
| New Hampshire | | | | | | | | |
| Coos | 200040014F05 | 96 | 115 | 56 | 54 | 359 | 176 | 169 |
| <u>Region II^d</u> | | | | | | | | |
| New Jersey | | | | | | | | |
| Hudson | 312320003F01 | 75 | 80 | | | 171 | | |
| Essex | 313480010F01 | 72 | 78 | | | 155 | | |
| New York | | | | | | | | |
| Erie | 330660005F01 | 70 | 78 | | | 172 | | |
| Niagara | 334740007F01 | 82 | 89 | | | 173 | | |
| Monroe | 335760001F01 | 88 | 110 | 54 | 56 | 338 | 166 | 172 |
| Onondaga | 336320002F01 | 68 | 76 | | | 197 | | |
| <u>Region III</u> | | | | | | | | |
| Maryland | | | | | | | | |
| Garrett | 210800001F01 | 68 | 76 | | | 185 | | |
| Pennsylvania | | | | | | | | |
| Lawrence | 396440015F01 | 78 | 86 | | | 163 | | |
| Mercer | 398140622F01 | 70 | 78 | | | 161 | | |
| West Virginia | | | | | | | | |
| Brooke | 500500004F02 | 71 | 80 | | | 180 | | |
| Hancock | 502000002F02 | 77 | 83 | | | 177 | | |
| <u>Region IV</u> | | | | | | | | |
| Alabama | | | | | | | | |
| Jefferson | 012140003G02 | 84 | 95 | | | 245 | | |
| Florida | | | | | | | | |
| Duval | 101960004H02 | 74 | 81 | | | 280 | | |

TABLE A.2 (Cont'd)

| Monitoring Station with the Highest Concentration in Its County | | Annual Arithmetic Average TSP Concentration ($\mu\text{g}/\text{m}^3$) | | Annual Arithmetic Average PM10 Concentration ^c ($\mu\text{g}/\text{m}^3$) | | Second Highest 24-hr Concentration ($\mu\text{g}/\text{m}^3$) | | |
|-----------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------|
| | | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | PM10 ^c | | |
| | | Geo- metric | Arith- metic | | | TSP | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio |
| Location | SAROAD Code ^b | | | | | | | |
| Region IV (Cont'd) | | | | | | | | |
| Kentucky | | | | | | | | |
| Carter | 180620002F01 | 65 | 82 | | | 272 | | |
| Jefferson | 182380020G01 | 75 | 81 | | | 143 | | |
| Daviess | 183140011F01 | 73 | 83 | | | 182 | | |
| McCracken | 183180004F01 | 78 | 100 | | 51 | 370 | 181 | 189 |
| Madison | 183500001F01 | 75 | 81 | | | 165 | | |
| Region V | | | | | | | | |
| Illinois | | | | | | | | |
| DuPage | 140380001F01 | 68 | 79 | | | 161 | | |
| Cook | 141220022H01 | 86 | 96 | | | 198 | | |
| Macon | 141740002F01 | 77 | 92 | | | 238 | | |
| St. Clair | 142120001F01 | 84 | 92 | | | 165 | | |
| Madison | 142960009F01 | 134 | 155 | 76 | 78 | 365 | 179 | 183 |
| Indiana | | | | | | | | |
| Clark | 150700004J03 | 66 | 117 | 57 | 59 | 607 | 297 | 304 |
| Lake | 151520016H01 | 90 | 110 | 54 | 55 | 411 | 201 | 206 |
| Jasper | 152100002J02 | 44 | 52 | | | 276 | | |
| Michigan | | | | | | | | |
| Wayne | 231140002G01 | - | - | | | 267 | | |
| Wayne | 231180023G02 | 91 | 101 | | 51 | 225 | | |
| Monroe | 233580004F01 | 69 | 80 | | | 196 | | |
| Minnesota | | | | | | | | |
| St. Louis | 241040025G01 | 65 | 91 | | | 291 | | |
| Ramsey | 243300018H01 | 68 | 80 | | | 203 | | |
| Stearns | 243950003H02 | 44 | 62 | | | 361 | 177 | 181 |
| Ohio | | | | | | | | |
| Wyandot | 361020001F02 | - | - | | | 288 | | |
| Hamilton | 365880001G01 | 78 | 85 | | | 170 | | |
| Cuyahoga | 361300013H01 | 101 | 112 | 55 | 56 | 255 | | |
| Columbiana | 361900003I01 | 88 | 100 | | | 229 | | |
| Jefferson | 363160013I02 | 80 | 95 | | | 280 | | |
| Jefferson | 364420001I02 | 118 | 128 | 63 | 64 | 214 | | |
| Butler | 364340005G01 | 73 | 81 | | | 197 | | |
| Sandusky | 365980009J02 | 99 | 129 | 63 | 65 | 477 | 233 | 239 |
| Belmont | 366100001I01 | 69 | 76 | | | 180 | | |
| Mahoning | 367760006I02 | 84 | 93 | | | 189 | | |
| Wisconsin | | | | | | | | |
| Kenosha | 511540016J02 | - | - | | | 270 | | |

TABLE A.2 (Cont'd)

| Monitoring Station with the Highest Concentration in Its County | | Annual Arithmetic Average TSP Concentration ($\mu\text{g}/\text{m}^3$) | | Annual Arithmetic Average PM10 Concentration ^c ($\mu\text{g}/\text{m}^3$) | | Second Highest 24-hr Concentration ($\mu\text{g}/\text{m}^3$) | | |
|-----------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|------------------------------------------------------|-----|
| | | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | PM10 ^c | | TSP |
| | | Geo- metric | Arith- metic | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | |
| Location | SAROAD Code ^b | | | | | | | |
| Region VI | | | | | | | | |
| New Mexico | | | | | | | | |
| Grant | 320090001F01 | - | - | | | | | 272 |
| Bernalillo | 320140013H01 | - | - | | | | | 293 |
| Dona Ana | 320340001F02 | - | - | | | | | 344 |
| McKinley | 320420001F02 | - | - | | | | 169 | 380 |
| Cibola | 320800002F01 | - | - | | | | 186 | 306 |
| Oklahoma | | | | | | | | |
| Tulsa | 372660138F01 | 72 | 77 | | | | | 173 |
| Texas | | | | | | | | |
| Taylor | 450010001F01 | 70 | 78 | | | | | 191 |
| Potter | 450070002F01 | 70 | 76 | | | | | 177 |
| Howard | 450440002F01 | 78 | 86 | | | | | 192 |
| Cameron | 450650003F01 | 85 | 94 | | | | | 249 |
| Brazoria | 450950003F01 | 75 | 81 | | | | | 156 |
| Nueces | 451150020G02 | 147 | 158 | 77 | 73 | | 151 | 308 |
| Ellis | 451690001F01 | 81 | 86 | | | | | 170 |
| El Paso | 451700030G01 | - | - | | | | 220 | 450 |
| El Paso | 451700002G01 | 112 | 125 | 61 | 58 | | | 302 |
| Tarrant | 451880003F01 | 78 | 84 | | | | | 159 |
| Harris | 452330025H02 | - | - | | | | 208 | 424 |
| Harris | 454060002F01 | 73 | 77 | | | | | 156 |
| Lubbock | 453340001F01 | 77 | 85 | | | | | 211 |
| Hidalgo | 453390003F01 | 74 | 78 | | | | | 162 |
| Ector | 453910002F01 | 71 | 81 | | | | | 193 |
| Bexar | 454570022G02 | 100 | 112 | 55 | 52 | | | 217 |
| Region VII | | | | | | | | |
| Iowa | | | | | | | | |
| Polk | 161180046G02 | 113 | 134 | 66 | 64 | | 199 | 406 |
| Kansas | | | | | | | | |
| Cloud | 170680001F01 | 70 | 78 | | | | | 126 |
| Sherman | 171240001F01 | 75 | 90 | | | | | 231 |
| Wyandotte | 171800015F02 | 71 | 77 | | | | | 147 |
| Nebraska | | | | | | | | |
| Cass | 280400005F09 | 85 | 101 | | | | | 266 |
| Lancaster | 281520002G09 | 71 | 82 | | | | | 161 |
| Scotts Bluff | 282240001F01 | 67 | 76 | | | | | 152 |
| Dakota | 282400003F01 | 78 | 86 | | | | | 156 |

TABLE A.2 (Cont'd)

| Monitoring Station with the Highest Concentration in Its County | | Annual Arithmetic Average TSP Concentration ($\mu\text{g}/\text{m}^3$) | | Annual Arithmetic Average PM10 Concentration ^c ($\mu\text{g}/\text{m}^3$) | | Second Highest 24-hr Concentration ($\mu\text{g}/\text{m}^3$) | | |
|-----------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|------------------------------------------------------|-----|
| | | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | PM10 ^c | | |
| | | | | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | |
| Location | SAROAD Code ^b | Geo- metric | Arith- metic | | | TSP | | |
| Region VIII ^e | | | | | | | | |
| Colorado | | | | | | | | |
| Adams | 060020001F01 | - | - | | | 281 | | |
| Archuleta | 060100001F01 | - | - | | | 309 | 151 | 151 |
| El Paso | 060380008F01 | - | - | | | 265 | | |
| Denver | 060580002F01 | - | - | | | 510 | 250 | 250 |
| Fremont | 060800001F01 | - | - | | | 366 | 179 | 179 |
| Prowers | 061280001F01 | - | - | | | 321 | 157 | 157 |
| San Miguel | 062000001F01 | - | - | | | 310 | 152 | 152 |
| Montana | | | | | | | | |
| Flathead | 270800015F01 | 74 | 85 | | | 232 | | |
| Cascade | 270660009G01 | 67 | 79 | | | 180 | | |
| Lincoln | 270900010F01 | 93 | 106 | 52 | 52 | 282 | | |
| Missoula | 271100020G01 | 55 | 65 | | | 313 | 153 | 153 |
| Missoula | 271100024G02 | 73 | 89 | | | 310 | | |
| Rosebud | 271360717J02 | 92 | 162 | 79 | 79 | 973 | 476 | 476 |
| South Dakota | | | | | | | | |
| Pennington | 431380001F01 | 58 | 69 | | | 275 | | |
| Wyoming | | | | | | | | |
| Sheridan | 520640001F01 | 63 | 76 | | | 262 | | |
| Region IX ^f | | | | | | | | |
| Arizona | | | | | | | | |
| Pima | 030020001F02 | - | - | | | 278 | | |
| Pima | 030860012G01 | 89 | 100 | | | 164 | | |
| Cochise | 030180010F02 | - | - | | | 693 | 340 | 298 |
| Gila | 030300001F02 | - | - | | | 455 | 223 | 196 |
| Maricopa | 030600013G01 | 116 | 128 | 63 | 55 | 228 | | |
| California | | | | | | | | |
| Kern | 050520003I01 | 104 | 112 | 55 | | 177 | | |
| Imperial | 050840003I01 | - | - | | | 372 | 182 | 160 |
| Imperial | 051000001I01 | 153 | 166 | 81 | 71 | 292 | | |
| Kings | 051640002I01 | 101 | 111 | 54 | | 249 | | |
| Fresno | 052800005F01 | 96 | 106 | 52 | | 173 | | |
| Inyo | 053460002I01 | 48 | 166 | 81 | 71 | 2,181 | 1,068 | 938 |
| Sutter | 054000001I01 | 68 | 76 | | | 153 | | |
| Orange | 054120002I01 | 86 | 94 | | | 188 | | |
| Stanislaus | 054720004F01 | 72 | 81 | | | 173 | | |
| Mono | 054760003I01 | 90 | 123 | 60 | 53 | 431 | 211 | 185 |
| Los Angeles | 055820001I01 | 84 | 94 | | | 195 | | |
| Riverside | 056535001I01 | 99 | 119 | 58 | 51 | 232 | | |
| San Bernardino | 056700006I01 | 93 | 106 | 52 | | 242 | | |

TABLE A.2 (Cont'd)

| Monitoring Station with the Highest Concentration in Its County | | Annual Arithmetic Average TSP Concentration ($\mu\text{g}/\text{m}^3$) | | Annual Arithmetic Average PM10 Concentration ^c ($\mu\text{g}/\text{m}^3$) | | Second Highest 24-hr Concentration ($\mu\text{g}/\text{m}^3$) | | |
|-----------------------------------------------------------------------|--------------------------|-----------------------------------------------------------------------------------|-----------------|-------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------|------------------------------------------------------|
| | | | | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio | PM10 ^c | | |
| | | Geo- metric | Arith- metic | | | TSP | Based On U.S. Average PM10/TSP Ratio | Based on Regional Average PM10/TSP Ratio |
| Location | SAROAD Code ^b | | | | | | | |
| <u>Region IX^f</u> (Cont'd) | | | | | | | | |
| California (Cont'd) | | | | | | | | |
| Ventura | 057670001I01 | 64 | 77 | | | 197 | | |
| Tulare | 058520002F01 | 85 | 100 | | | 169 | | |
| Nevada | | | | | | | | |
| Washoe | 290540006I01 | 89 | 111 | 54 | | 253 | | |
| <u>Region X</u> | | | | | | | | |
| Arkansas | | | | | | | | |
| Anchorage | 020060004I03 | - | - | | | 334 | 164 | 154 |
| Fairbanks N. | 020160015G01 | 71 | 81 | | | 183 | | |
| Fairbanks N. | 020160016G01 | 72 | 81 | | | 187 | | |
| Idaho | | | | | | | | |
| Bannock | 130080004F02 | 104 | 116 | 57 | 53 | 231 | | |
| Ada | 130220009F01 | 76 | 88 | | | 284 | | |
| Caribuo | 130420014F02 | 102 | 127 | 62 | 58 | 391 | 192 | 180 |
| Shoshone | 131420017F02 | 93 | 117 | 57 | 54 | 504 | 247 | 232 |
| Oregon | | | | | | | | |
| Umatilla | 381420002F01 | 84 | 91 | | | 160 | | |
| Washington | | | | | | | | |
| King | 491840057I02 | 74 | 83 | | | 215 | | |
| Spokane | 492040016I01 | 112 | 138 | 68 | 63 | 370 | 181 | 170 |
| Pierce | 492140004I02 | 68 | 79 | | | 209 | | |
| Clark | 492220003I02 | 88 | 112 | 55 | 52 | 342 | 168 | 157 |
| Yakima | 492440006F01 | 66 | 77 | | | 187 | | |

^aThe counties listed are those in nonattainment of either (1) $75 \mu\text{g}/\text{m}^3$ as the annual TSP average (geometric or average or (2) $260 \mu\text{g}/\text{m}^3$ as the second highest 24-hr concentration in a year.

^bCode assigned by EPA to each monitoring station reporting data to the Storage and Retrieval of Aerometric Data (SAROAD) system.

^cValues are only presented if they exceed the lowest ambient standard currently under consideration, i.e., $50 \mu\text{g}/\text{m}^3$ for the annual average and $150 \mu\text{g}/\text{m}^3$ for the 24-hr maximum.

^dExcludes Puerto Rico data.

^eThe U.S. annual average ratio was used for calculating all Region VIII data.

^fExcludes Guam data.

ARGONNE NATIONAL LAB WEST



3 4444 00031578 8

X